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Sensitivity Analysis of the Enhanced Simulation of Human Air Pollution Exposure (SHAPE) Model

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A SENSITIVITY ANALYSIS OF THE ENHANCED SIMULATION OF HUMAN AIR POLLUTION EXPOSURE (SHAPE) MODEL

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ABSTRACT

A sensitivity analysis was undertaken of the Simulation of Human Air Pollution Exposure (SHAPE) model, which incorporates an enhanced version of the Coburn-Forster-Kane (CFK) physiological model for predicting a person's blood carboxyhemoglobin (COHb) as a function of time in response to carbon monoxide (CO) exposure. The SHAPE model simulates the physical activities of a sample of people in an urban area, exposing them to pollutant concentrations from appropriate microenvironments as they move through time and space in a 24-hour period. The CFK model dynamically calculates their blood COHb from their CO exposures, and the person's ventilation rate is altered in response to their level of activity. To conduct this sensitivity analysis, the SHAPE program was run many times using different combinations of values for its parameters, thus allowing the contribution to COHb of each of many variables to be examined. The following phenomena were found to have significant effect, over and above the influence of the ambient CO on the predicted frequency distribution of the maximum COHb levels of the population: (1) CO exposure contributed by the highway microenvironment; (2) altitude of the city; (3) the CFK physiological parameters (e.g., Haldane constant and endogenous CO production). In contrast, if it is assumed that a person using an indoor parking garage spends less than 10 minutes there, then use of a parking garage has very little effect on the COHb frequency distribution of the population. For low-level CO exposure, use of either the linear or nonlinear form of the CFK model yields essentially the same results.

EXECUTIVE SUMMARY

The Simulation of Human Air Pollution Exposure (SHAPE) model estimates human exposure to carbon monoxide (CO). It develops an "activity pattern profile" for an individual by allocating each minute of the day into any of 14 microenvironments (home, car, office, parking garage, etc). By knowing where the person is and approximately what he or she is doing, another part of the program "exposes" the person to CO concentrations appropriate for that microenvironment. Random number generators provide minute-by-minute concentration levels roughly equivalent to those found in the actual microenvironment, based on empirical field studies. For each person, these sequential microenvironmental exposures are brought together to form an "exposure profile" providing CO concentration and estimates of the carboxyhemoglobin (COHb) of the blood as functions of time over the 24-hour period.

The previous version of the SHAPE program used a simplified Coburn CO-COHb model, a first-order linear differential equation with three constant coefficients. This formulation did not permit physiological and other subcomponent parameters (for example, blood volume, ventilation rate, altitude) to be varied by themselves, because the latter parameters were lumped together into the three constants.

The research summarized here covers enhancements to the SHAPE model and a sensitivity analysis of the enhanced model.

The goal of this analysis is to determine how changes in a variety of fundamental parameters (highway CO concentrations, CO concentrations inside a parking garage, time patterns of ambient CO concentrations, and various Coburn physiological parameters) affect the following three dependent variables for the population:

- Maximum 1-hour average exposure (M1AE)
- Maximum moving 8-hour average exposure (MM8AE)
- Maximum 1-hour blood carboxyhemoglobin (M1COHb)

In each case, we are interested in the population's frequency distributions of these variables and the impact of a change in each parameter on these frequency distributions. In general, we examined changes in frequency distributions that result while one parameter is allowed to vary and all the others are held constant. In some cases, two parameters were varied at the same time.

Our simulation sample consisted of 400 non-smoking people employed in a large urban area. Their simulated commute habits are based on data from the U.S. Census Bureau's "Nationwide Personal Transportation Study", (1973).

The following enhancements have been made to the SHAPE computer program:

- All individual Coburn parameters appear explicitly.
- Both linear and the more accurate nonlinear versions of the Coburn model can be used to compute blood COHb.
- Once the age and sex of the person have been established, height is determined by random sampling from distributions based on data from the National Health and Nutrition Examination Survey (HANES) conducted by the National Center for Health Statistics.
- Weight is determined from empirical height-weight equations, also based on sex and age.
- Blood volume is determined from height and weight, and hemoglobin content is randomly sampled from the HANES data, based on sex.
- Some of the person's lung functions (alveolar ventilation and diffusion rates, for example) are allowed to vary throughout the day and are determined from the activities he or she performs, based on metabolic rate assumptions for each physical activity level.
- For each person, the program runs through an extra 24-hour exposure sequence on the previous day in order to set the initial conditions for the day of interest.

Once these enhancements were made, the program was run many times with different combinations of values. Ambient data for three different dates were used, each with relatively high CO levels (Table 4), selected from an earlier sensitivity analysis.

In this study, only subsamples of an urban population were simulated for their exposure experience to CO. The subsample consisted of nonsmoking employed commuters during a week day. As such the distributions generated of maximum 1 hour CO exposure, maximum 8 hr exposure and maximum 1 hour COHb are seen to have small standard deviations and less than 10% coefficients of variation.

The highlights from the study are:

- Changes in CO levels inside automobiles exert a statistically significant effect on computed blood COHb of the population.
- Altitude exerts a statistically significant effect on computed blood COHb.

- Changes in the levels of CO in indoor parking garages have little effect on total CO exposure and blood COHb of the population due to the brief time (10 minutes) assumed spent there.

- For low-level CO exposure, the linear approximation of the solution to the Coburn equation does not differ significantly from the nonlinear solution.

This sensitivity analysis has identified the relative significance of a variety of parameters in generating estimates of blood COHb and has provided insight into the manner in which the parameters affect person-to-person variability of blood COHb. It also has identified the likely contribution of various human activities -- driving a car, parking in a garage -- to population exposure distributions and human dose distributions.

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I. INTRODUCTION

Over the last decade, a number of field studies have shown that conventional air monitoring stations do not necessarily provide data indicative of the pollutant concentrations that people actually come into contact with in their daily lives. An obvious reason for the discrepancy between a person's exposure to a pollutant and the measurements at a fixed monitoring station is that people move around and engage in a variety of activities, thereby coming into close contact with the sources of many pollutants, while monitoring stations stay in one location, which may or may not be representative of the population's exposure to the pollution. If one is to compare a fixed station's 24-hour concentration record with the exposures received by the population, then an obvious question arises, "Which person will we choose for comparison with the fixed station, since person-to-person exposures will vary?" Should we choose the person with the average of all the exposures in the population or the person with the highest exposure in the population? Recently, interest has focused on the frequency distribution of exposures of the population. How are we to determine that frequency distribution? With each person's exposure profile (concentration as a function of time), we can also assume there exists a dose profile (concentration absorbed into the body as a function of time). Consequently, there also exists a frequency distribution of the resulting dose levels of the population. How can we determine that frequency distribution?

Two approaches have been suggested for determining exposure and dose frequency distributions of urban populations. The direct approach consists of direct measurements with small, portable personal monitors. These instruments are given to respondents in the population, and their exposures are measured directly. Similarly, their doses can be measured directly by taking samples of their blood or breath. In 1982-83, two pioneering field studies using the direct measurement approach for CO were conducted in Denver, Colo. and Washington, D.C. The findings from these studies are still being analyzed.

As an alternative, the indirect approach consists of combining information on the times people spend in specific locations ("microenvironments") with the concentrations associated with those microenvironments. By merging the time-activity information with the concentration information, it is possible to calculate an exposure profile for the person, or for many persons.

The Simulation of Human Air Pollution Exposure (SHAPE) model used in the present investigation is an example of the indirect approach. Simulation methodology used in SHAPE is discussed in Appendix C - Section 5 of this report. Since its original development in 1980-81 (Ott, 1983-84), a number of enhancements were found necessary, and these were carried out as part of the present project. The SHAPE model estimates human exposure to carbon monoxide (CO) using concentrations in both ambient air and 14 "microenvironments" (listed in Appendix A) through which an individual passes during the day. It models an individual's daily activities, using probability distributions with parameters estimated from studies of activity patterns. The result is a minute-by-minute activity profile for a 24-hour period. CO exposure is sampled in each microenvironment using a lognormal distribution, with given geometric mean and standard geometric deviation derived from air pollution field studies (Appendix A). Based on the activity profile, SHAPE generates a minute-by-minute CO exposure profile. Average hourly microenvironmental CO exposures are then calculated by averaging 60 1-minute values. The hourly ambient CO concentration, gathered from various monitoring stations, is added to the average hourly microenvironmental CO to give the 1-hour average CO exposure for the individual sampled.

The moving 8-hour averages of CO exposures are also calculated. For each individual, the maximum 1-hour average CO exposure (M1AE) and the maximum moving 8-hour average CO exposure (MM8AE) in a 24-hour period are identified and stored. From the 1-hour average CO exposure, SHAPE estimates the individual's blood carboxyhemoglobin (COHb) level dynamically over the 24 hours, using the Coburn equation (Coburn et al., 1965). The maximum 1-hour COHb level (M1COHb) is also obtained from the estimates of 24 hourly levels.

A. Intrinsic Assumptions Within SHAPE

SHAPE models human activities stochastically according to the following rules:

- Selection of any activity is based on a probability distribution specified by the user.
- The duration of each activity is a random variable, based on the activity selected and generated from a conditional probability distribution specified by the user.
- Once an activity is selected, it remains in effect during the time specified.
- If desired, activity selection can be conditioned on the outcome of previous activities.

Each activity corresponds to a particular microenvironment. Thus, if a person is driving home, the relevant microenvironment is the automobile. SHAPE, however, also models the minute-to-minute variation in CO concentrations inside the automobile in a stochastic fashion. For each microenvironment selected, it assumes that the 1-minute average CO concentrations are lognormally distributed. The two parameters used to specify these lognormal distributions are based on field studies in various microenvironments (Ott, 1983).

The total exposure one receives at a given location is assumed to be the sum of the ambient concentration at that location and the concentration contributed by the microenvironment. If the microenvironment contains no sources, it then makes no contribution and only the ambient concentrations are used. On the other hand, if a microenvironment contains sources (e.g., a parking garage), then the individual values associated with parking garages are added to the ambient concentrations to arrive at the total exposures for that location.

B. Enhancements

Several enhancements have been made to SHAPE. The first updates various probability distributions of several demographic variables of the U.S. population. The 1980 Census and the second National Health and Nutrition Examination Survey (HANES II), conducted in 1976-1980 by the National Center for Health Statistics, provide new data on sex, age, height, and blood hemoglobin content of the U.S. population (Appendix B). This information permits calculating a person's weight, blood volume, and basal diffusion rate.

The second enhancement incorporates new formulae that permit inclusion of the barometric pressure for a given altitude and the mean capillary oxygen tension, using metabolic rates generated from the minute-by-minute activity profile to calculate the hourly alveolar ventilation and the lung diffusion (Appendix C).

The third enhancement incorporates a nonlinear solution of the Coburn model. SHAPE originally used a linear solution of the Coburn equation derived by Ott and Mage (1978). This approximation did not take into account the physiological variations among individuals. In our work, we modified the program to use physiological information to reflect the variation among individuals and to use the nonlinear solution of the Coburn equation derived by Marcus (1981). We then compared the two solutions (Section II).

COHb levels in the blood are dynamic over a period of time. The levels estimated for an individual over a 24-hour period depend on the person's COHb at the start of the period under study. An important enhancement to SHAPE involves the realistic estimation of the initial COHb level for each person. In the previous program, it was assumed to be zero. SHAPE made a run for each individual over two 24-hour periods, the day under study and the previous day. The ambient CO concentrations of the previous day are used with the activity pattern of the day under study to arrive at the initial COHb for the day under study. Until SHAPE acquires activity patterns for weekends, it must assume that the only determinant of the initial COHb level is the ambient CO of the previous day.

C. Sensitivity Analysis

In the sensitivity analysis, we studied the ambient CO exposure, which contributes a great deal to an individual's total CO exposure. Ambient CO data were obtained from the Caliornia Air Resources Board: (1) Nov. 24, 1970, in San Jose, (2) Jan. 2, 1975, in Los Angeles County, and (3) Feb. 11, 1976, in Whittier. SHAPE also was run using only the ambient CO exposure, with the microenvironmental CO exposure set to zero, to study the ambient CO effect in isolation as well as in conjunction with the microenvironmental CO. (Section III).

In another phase of the sensitivity analysis, we studied two sets of parameters used in the SHAPE program. One contains parameters associated with CO concentrations in microenvironments 5 (parking garage) and 6 (automobile); the other contains three constants used in the Coburn equation--altitude, endogenous CO production rate, and the Haldane constant. For altitude, two values were used; for the other two, three were used. We studied the effects of CO concentration in parking garages along with the probability of using a parking garage. Similarly, we studied the relationship between CO concentration in automobiles and the home-work commuting time. Cumulative percent distributions of M1AE, MM8AE, and M1COHb were obtained, and the results were analyzed, with a statistical computing package called SAS (Section IV). The combined effects of altitude, endogenous CO production rate, and the Haldane constant also were studied (Section V).

The sample for each computer run was set at 400, which was adequate for statistical analysis and produced meaningful results. All simulations used the same random number seed and in most cases generated the same group of people with the same physiological characteristics. (Different samples were generated when a person's activity pattern changed). This eliminated sample-to-sample variations and allowed us to study the true effect of the parameters of interest. The step-by-step calculation of the hourly COHb levels is included in Appendix C.

The source listing of the SHAPE Fortran program is included as Appendix E of this report. A new version of this simulation program, which can run on the IBM PC/XT/AT microcomputer is available on diskette.

II. COMPARISON OF LINEAR AND NONLINEAR SOLUTIONS IN ESTIMATION OF BLOOD COHb

The Coburn equation for estimating blood COHb due to a specified CO exposure is now almost 20 years old. Because of the equation's complexity, several versions of its linear approximation have been used by researchers, including Peterson and Stewart (1975), Ott and Mage (1978), Marcus (1980), and Biller and Richmond (1982). For low CO exposure, the linear approximation is adequate. However, the computer makes it easy to use the more accurate nonlinear iterative solution derived by Marcus (1981). The Coburn equation and its solutions, along with the algorithms used in the program, are presented in Appendix C.

All aspects of using linear or nonlinear estimations of COHb in the SHAPE model were compared. The model was run with altitude at 0 feet, endogenous CO production ($\dot{V}_{CO}$) at 0.007 milliliters per minute (ml/min), and the Haldane constant (M) at 230. Ambient CO concentration data used were collected on Feb. 11, 1976, in Whittier, Calif., and were obtained from the State of California's Air Resources Board.

The comparison was done in two phases. In phase 1, we wanted to see if the two solutions diverge over time. The starting COHb levels were forced to be the same for both linear and nonlinear methods. Hourly COHb levels from both methods were determined on five people (Table 1). The results indicate that the errors do not propagate to become significant, the maximum difference being only 0.0027%.

In phase 2, the regular SHAPE model was run with 400 people to compare the linear and nonlinear distributions of M1COHb levels. The starting COHb levels were different, since the previous day's COHb levels were estimated by different methods. Cumulative distributions of M1COHb are almost identical (Table 2, Figure 1). For example, the percentage of people with M1COHb levels 2.5% and above is 31.25% for the linear form and 29.50% for the nonlinear form. Note that the vertical scale of all cumulative distribution curves is modified to give a clear view in the 80 to 100 percent range. Entries in the tables represent percentages of people equal to or greater than the values specified.

The differences between the two estimates (Figure 2) show that the linear method overestimates the M1COHb. The differences--of the order of less than 0.01%--are not significant.

Since the ambient CO exposures on Feb. 11, 1976, in Whittier were not large enough to show differences between linear and nonlinear COHb estimates, we used the ambient San Jose CO data from Feb. 11, 1971, which were higher. Even then, the differences between them were not significant, ranging only from 0 to 0.003%. Then the ambient CO concentrations were doubled to near 45 parts per million (ppm). The 1971 ambient CO and the 24 hourly COHb levels on one person (Table 3, Figure 3) show a maximum difference of 0.02%; this difference is not visible. The M1COHb cumulative distributions by the two methods (Figure 4) show some differences. However, CO levels of 45 ppm are not likely to occur often in nature.

TABLE 1 : TWENTY-FOUR HOURLY LINEAR AND NONLINEAR COHB LEVELS(PERCENT) OF 5 PEOPLE FROM SHAPE SIMULATION

HOUR	CO (PPM)	PERSON 1 LINEAR	PERSON 1 NONLNR	PERSON 2 LINEAR	PERSON 2 NONLNR	PERSON 3 LINEAR	PERSON 3 NONLNR	PERSON 4 LINEAR	PERSON 4 NONLNR	PERSON 5 LINEAR	PERSON 5 NONLNR
.	.	1.7620	1.7620	1.8205	1.8205	1.7528	1.7528	1.8139	1.8139	1.7743	1.7743
0	9.00	1.7058	1.7057	1.7426	1.7423	1.6991	1.6989	1.7408	1.7406	1.7156	1.7154
1	8.00	1.6308	1.6305	1.6473	1.6469	1.6262	1.6260	1.6501	1.6497	1.6384	1.6381
2	8.00	1.5697	1.5693	1.5726	1.5720	1.5667	1.5663	1.5781	1.5776	1.5754	1.5751
3	7.00	1.4904	1.4900	1.4797	1.4791	1.4890	1.4886	1.4881	1.4877	1.4946	1.4944
4	6.00	1.3965	1.3961	1.3726	1.3720	1.3965	1.3962	1.3840	1.3836	1.3994	1.3991
5	9.00	1.4075	1.4072	1.3906	1.3902	1.4074	1.4072	1.3989	1.3986	1.4100	1.4098
6	13.00	1.5983	1.5983	1.6124	1.6128	1.5946	1.5946	1.6706	1.6712	1.7074	1.7077
7	24.86	2.2817	2.2844	2.3708	2.3731	2.2741	2.2767	2.3852	2.3875	2.3039	2.3066
8	13.00	2.2315	2.2333	2.2825	2.2838	2.2223	2.2240	2.3004	2.3019	2.2477	2.2496
9	6.00	1.9082	1.9083	1.8990	1.8982	1.9074	1.9074	1.9266	1.9260	1.9198	1.9199
10	5.00	1.6276	1.6269	1.5817	1.5805	1.6321	1.6315	1.6138	1.6126	1.6358	1.6352
11	3.12	1.3425	1.3413	1.2946	1.2930	1.3917	1.3910	1.3520	1.3505	1.4276	1.4264
12	2.08	1.0878	1.0865	1.0433	1.0415	1.1705	1.1699	1.1157	1.1142	1.1562	1.1547
1	2.00	0.8950	0.8938	0.8367	0.8349	0.9603	0.9598	0.8966	0.8951	0.9454	0.9443
2	2.00	0.7514	0.7503	0.6899	0.6884	0.8032	0.8025	0.7387	0.7375	0.7888	0.7877
3	2.00	0.6442	0.6434	0.5856	0.5845	0.6851	0.6845	0.6248	0.6239	0.6720	0.6711
4	6.76	0.7724	0.7720	0.6521	0.6514	0.7175	0.7171	0.8057	0.8055	0.8678	0.8674
5	7.00	0.8729	0.8726	0.8280	0.8279	0.8723	0.8724	0.9383	0.9383	0.9549	0.9547
6	7.00	0.9456	0.9455	0.9248	0.9248	0.9438	0.9440	0.9981	0.9982	1.0050	1.0050
7	8.00	1.0427	1.0427	1.0415	1.0418	1.0396	1.0397	1.0884	1.0886	1.0858	1.0858
8	9.00	1.1573	1.1575	1.1721	1.1725	1.1528	1.1531	1.1998	1.2002	1.1886	1.1887
9	14.00	1.4620	1.4625	1.5136	1.5144	1.4528	1.4534	1.5199	1.5207	1.4847	1.4853
10	12.00	1.5930	1.5938	1.6462	1.6472	1.5839	1.5847	1.6456	1.6465	1.6095	1.6103
11	12.00	1.6877	1.6885	1.7369	1.7378	1.6792	1.6801	1.7330	1.7339	1.6996	1.7004

DATE= 2/11/76, ALTITUDE= 0 FT., UCO= .007 ML/MIN., HALDANE CONSTANT= 230,
MUS= 27.56 PPM, PROBABILITY OF PARKING GARAGE USE= .10, MLG= 7.8 PPM, NO EXTRA COMMUTING TIME

```
TABLE  2  :     CUMULATIVE DISTRIBUTIONS OF MAXIMUM 1-HOUR COHB LEVELS(MICOHB)
                OF 400 PEOPLE FROM SHAPE SIMULATION

                LINEAR NONLINEAR METHOD COMPARISON

--------------------------------------------------------------------------------

                   MICOHB
                  (PERCENT)       LINEAR          NONLINEAR
                                 --------        ---------

                    3.3            0.00            0.00
                    3.2            0.25            0.25
                    3.1            0.25            0.25
                    3.0            0.75            0.75
                    2.9            1.50            1.50
                    2.8            3.50            3.25
                    2.7            8.50            8.25
                    2.6           16.50           16.25
                    2.5           31.25           29.50
                    2.4           66.25           65.50
                    2.3           90.00           89.50
                    2.2           98.25           98.25
                    2.1          100.00          100.00

--------------------------------------------------------------------------------

DATE= FEB. 11, 1976,  ALTITUDE=     0 FT.
GEOMETRIC MEAN AND STANDARD DEVIATION OF CO CONCENTRATION IN PARKING GARAGES:
  MU5=27.56 PPM, SIGMA5=1.79
PROBABILITY OF USING PARKING GARAGE= .10
GEOMETRIC MEAN AND STANDARD DEVIATION OF CO CONCENTRATION IN AUTOMOBILES:
  MU6= 7.80 PPM, SIGMA6=2.53
NO EXTRA COMMUTING TIME
```

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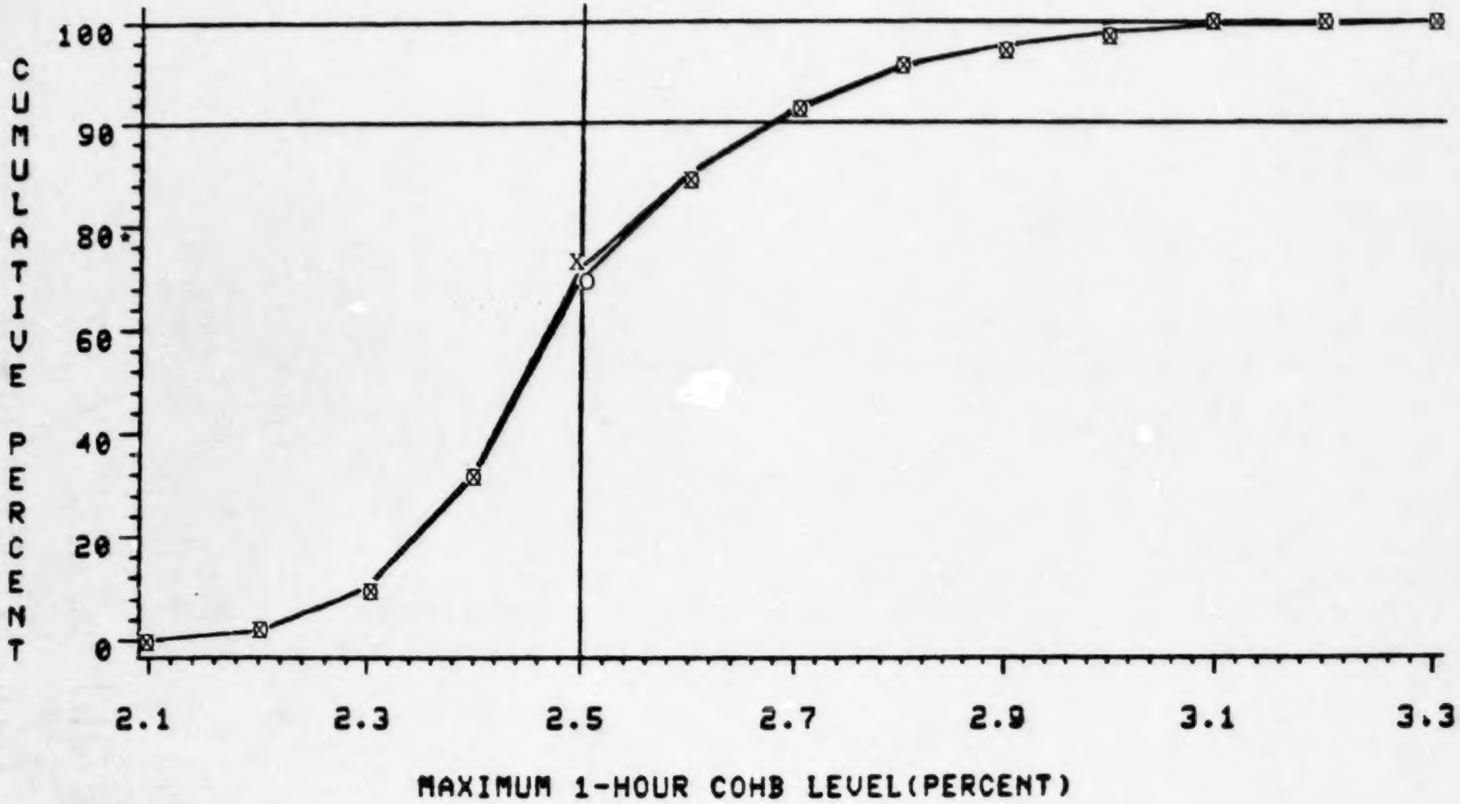
FIGURE 1 : MAXIMUM 1-HOUR BLOOD COHB LEVEL

LINEAR NONLINEAR COMPARISON



LEGEND O-O : LINEAR
X-X: NONLINEAR

DISTRIBUTION OF M1COHB OF 400 PEOPLE
SHAPE SIMULATION MODEL
DATE=021176, VCO=.007 ML/MIN, HALDANE=230
MU5=27.56 PPM, GARAGE USE=.10, MU6=7.8 PPM, NO EXTRA COMMUTING TIME

* NOTE THE CHANGE IN SCALE

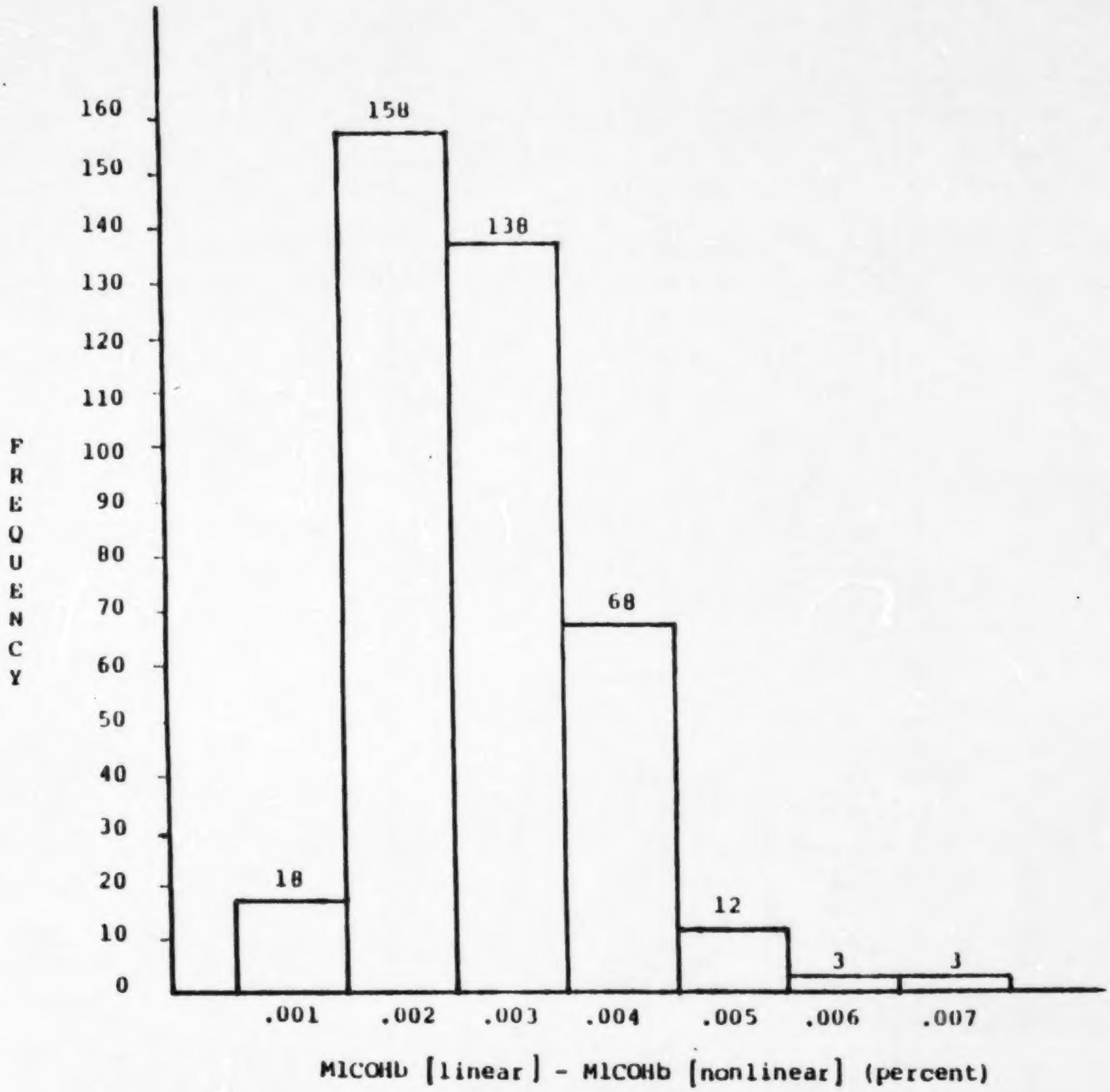


FIGURE 2: Frequency Distribution of Differences in Maximum 1-Hour Blood COHb Levels of 400 People: Linear vs. Nonlinear Methods

Date: 02/11/76, altitude=0 ft, V_{CO}=0.007 ml/min, Haldane Constant=230, mu5=27.56 ppm, garage use=0.10, mu6=7.8 ppm, no extra commuting time

TABLE 3. Hourly COHb of One Individual: Linear vs. Nonlinear Methods

		COHb (percent)			
		(Normal Ambient CO)		(Double Ambient CO)	
Hour of Day	Ambient CO Concentration (ppm)	Linear	Nonlinear	Linear	Nonlinear
0	21	2.887	2.884	5.238	5.227
1	15	2.895	2.892	5.229	5.221
2	11	2.785	2.783	4.989	4.984
3	10	2.666	2.665	4.738	4.735
4	9	2.541	2.540	4.478	4.476
5	6	2.351	2.351	4.093	4.094
6	8	2.182	2.183	3.777	3.779
7	18	2.552	2.550	4.496	4.492
8	7	2.264	2.265	3.975	3.975
9	7	2.052	2.053	3.595	3.597
10	4	1.773	1.774	3.072	3.075
11	4	1.584	1.585	2.706	2.711
12	3	1.400	1.401	2.352	2.357
1	3	1.248	1.249	2.076	2.081
2	5	1.217	1.218	2.037	2.040
3	6	1.236	1.236	2.089	2.092
4	7	1.362	1.362	2.289	2.290
5	9	1.515	1.515	2.581	2.580
6	7	1.537	1.537	2.613	2.612
7	6	1.509	1.509	2.547	2.547
8	8	1.577	1.577	2.678	2.677
9	10	1.715	1.714	2.948	2.946
10	10	1.814	1.814	3.141	3.139
11	9	1.841	1.841	3.190	3.188

Date: Feb. 11, 1971
Female
Age: 23
Height: 67 in
Weight: 141 lb
Hemoglobin content = 14.4 g/100 ml
Altitude = 0 ft
V_{CO} = 0.007 ml/min
Haldane Constant = 230

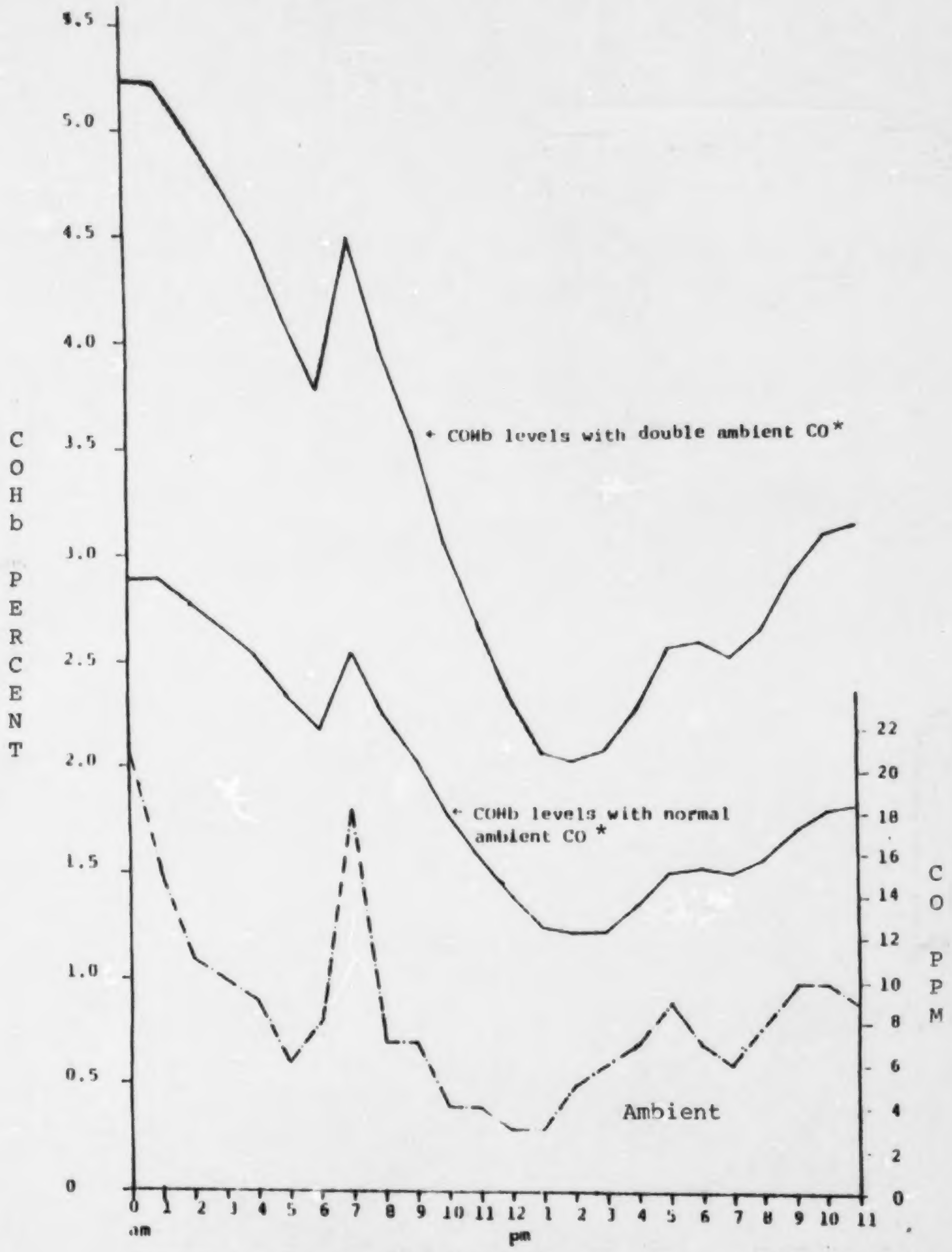
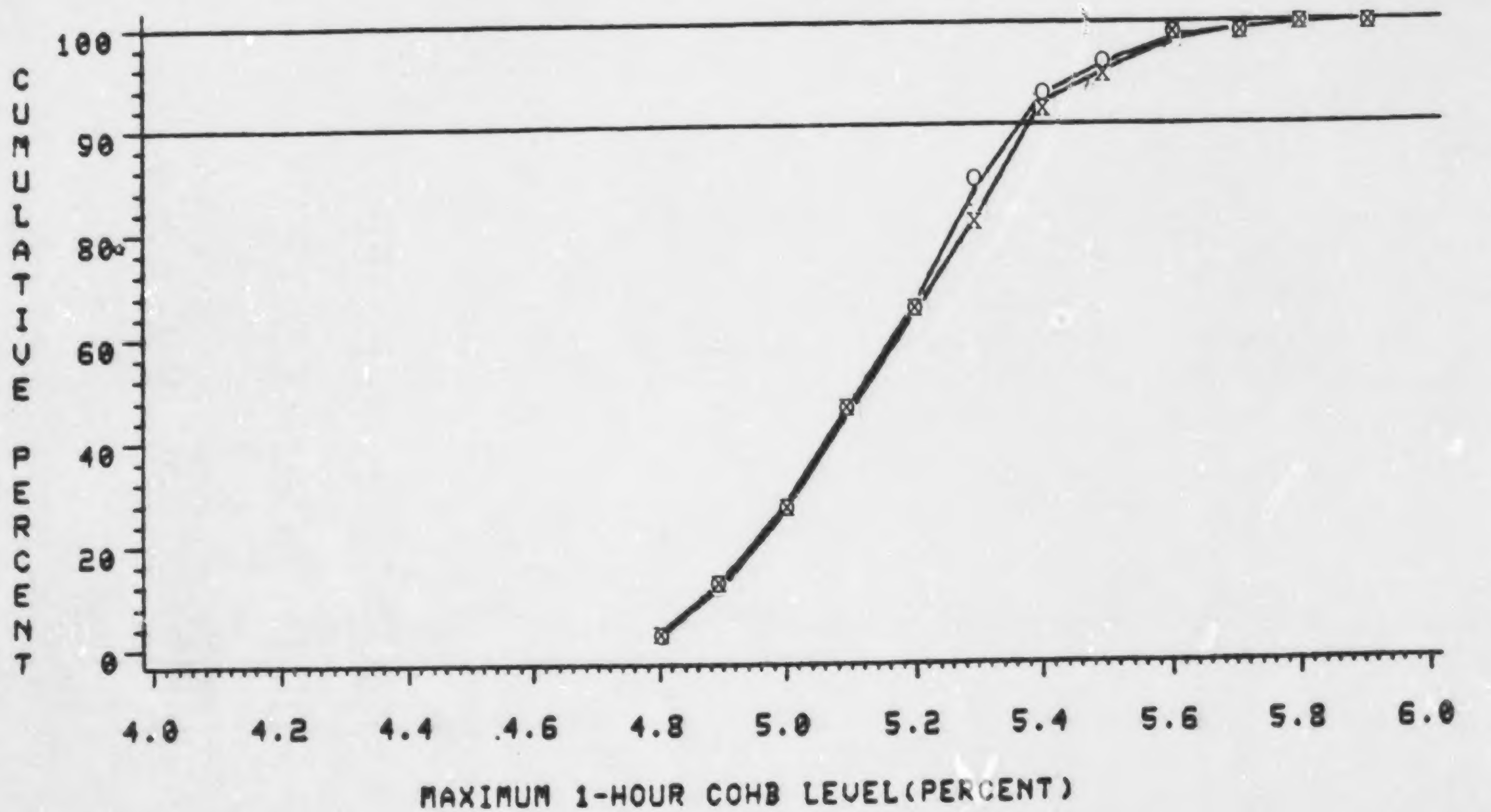


FIGURE 3: Hourly Blood COHb Level of One Individual and Ambient CO Concentration: *Linear and Nonlinear Methods overlap.

Date: 02/11/71, female, age 23, height 67 in, weight 141 lbs, hemoglobin content=14.4 g/100 ml, altitude=0 ft, V_{CO}=0.007 ml/min, Haldane Constant=230

FIGURE 4: MAXIMUM 1-HOUR BLOOD COHB LEVEL

LINEAR VS NONLINEAR (DOUBLE AMBIENT)



DISTRIBUTION OF M1COHB OF 400 PEOPLE
SHAPE SIMULATION MODEL
DATE=021171, VCO=.007 ML/MIN, HALDANE=230
MUS=27.56 PPM, GARAGE USE=.10, MUG=7.8 PPM, NO EXTRA COMMUTING TIME

* NOTE THE CHANGE IN SCALE

Our results indicate that for low CO exposure, the two approximations do not differ significantly. However, the nonlinear estimation involves an iterative procedure, which can increase computer costs significantly if the solution does not converge efficiently. For a simulation of 400 people, the central processing unit time was 37.93 seconds for the linear method and 41.89 seconds for the nonlinear one; computer costs were $3.57 and $3.95, respectively. Since computer costs are comparable, we will use the more accurate nonlinear method in the SHAPE program.

III. COMPARISON OF EFFECTS OF VARYING AMBIENT CO WITH AND WITHOUT MICROENVIRONMENT EXPOSURES

In our research on the effects of ambient CO concentration patterns on CO exposure and COHb estimates, we compared ambient CO data from the three California sites (Table 4, Figure 5). These dates were chosen because they had maximum 8-hour average values of about 9 ppm, the EPA's national standard. SHAPE was first run using only the ambient CO exposures by setting the microenvironmental CO exposure to zero. Since there was no microenvironmental CO exposure component, M1AE and MM8AE were the same for all 400 people in the simulation. Physiological variations and different daily activities produced different M1COHb levels among the 400 people (Table 5, Figure 6). With the maximum 1-hour CO exposure at 22 ppm, the M1COHb levels were all below 2.5%. When the microenvironmental CO exposure component was included, however, the distributions of M1AE, MM8AE, and M1COHb changed drastically, especially for data collected Feb. 11, 1976 (Table 6 and Figures 7.1, 7.2 and 7.3). Including the microenvironmental CO exposure, the percentage of people with M1COHb levels 2.5% and above increased from 0 to 24. This shows that using only ambient CO monitoring stations without consideration of CO levels in various microenvironments to estimate human exposure to CO may be inadequate. The changes in cumulative distribution of M1COHb with and without microenvironmental exposures on Nov. 24, 1970, and Jan. 2, 1975, seemed similar, but were quite different from that of Feb. 11, 1976 (Figure 6 and 7.3). This difference is caused by the fact that the maximum M1COHb occurred at different times during the days shown on Figure 6.

The results using the CO data of Feb. 11, 1976, are presented for the rest of this report. The results of the simulation using data from the other two days are summarized in the same format in Appendix D.

TABLE 4. Ambient CO Concentrations at Three Urban Monitoring Sites

Hour of Day	San Jose, CA		Los Angeles Co., CA		Whittier, CA	
	11/23/70	11/24/70	1/1/75	1/2/75	2/10/76	2/11/76
			(parts per million)			
0 am	5	10		13		7
1	3	10		13		6
2	3	8		11		6
3	3	7		10		5
4	3	6		7		4
5	3	5		6		7
6	4	6		2		11
7	5	9		2		22
8	4	10	1	2	4	12
9	4	7	1	1	1	5
10	4	5	1	1	1	4
11	4	4	1	1	1	2
12 pm	5	5	1	1	1	1
1	5	5	1	1	1	1
2	5	4	1	1	1	1
3	6	4	1	1	2	1
4	9	8	1	2	2	4
5	12	5	2	2	5	5
6	12	4	3	4	6	5
7	12	4	5	6	8	6
8	14	3	8	5	12	7
9	17	3	12	7	10	12
10	11	2	14	8	11	10
11	8	2	14	8	10	10
Mean (1-hour)		5.667		4.792		6.417
Standard Deviation (1-hour)		2.46		4.032		4.736
Min. (1-hour)		2		1		1
Max. (1-hour)		10		13		22
Max. (8-hour)		12.0		9.5		8.2

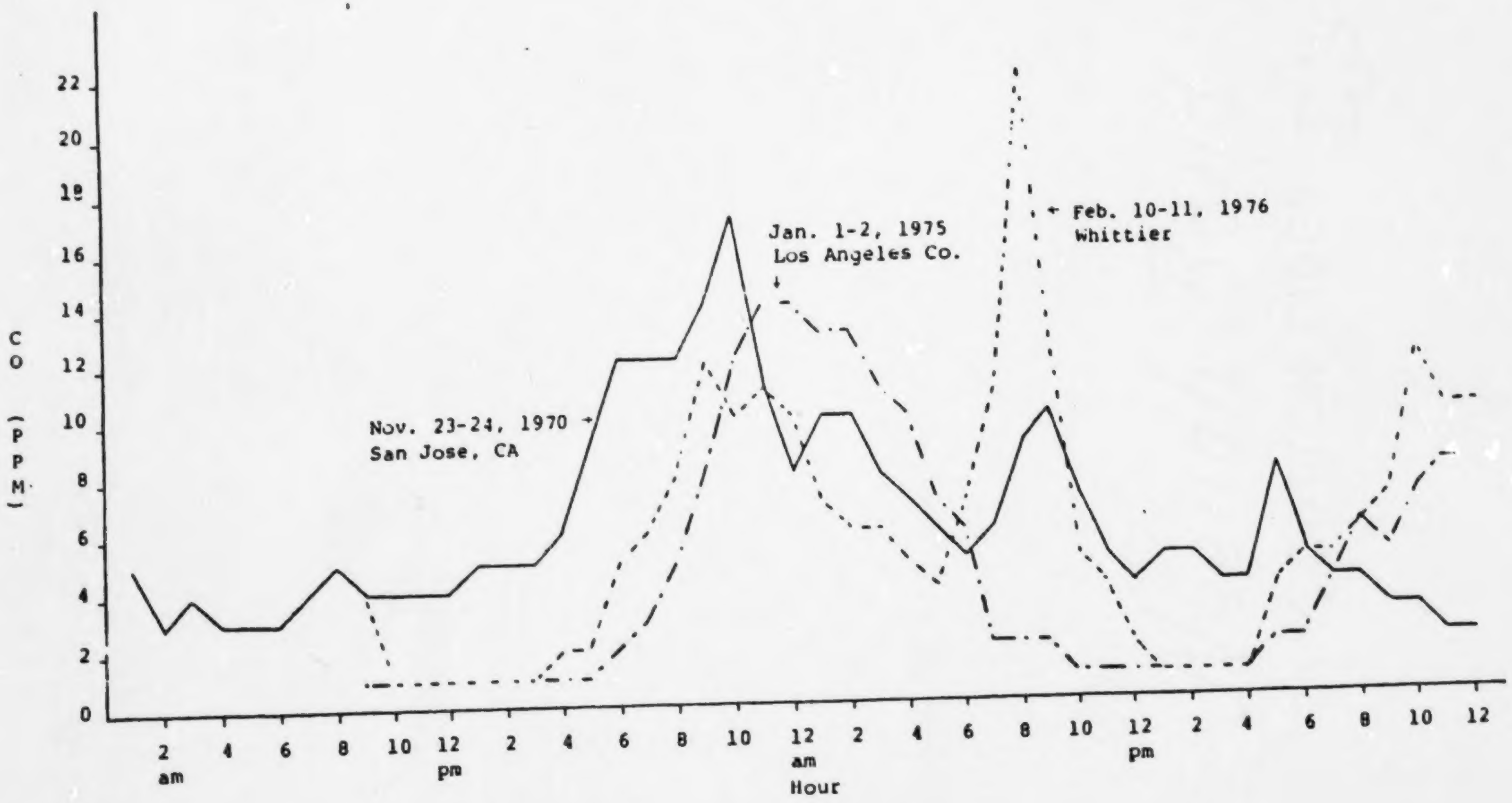


FIGURE 5: Hourly CO Concentrations at Three Urban Monitoring Sites

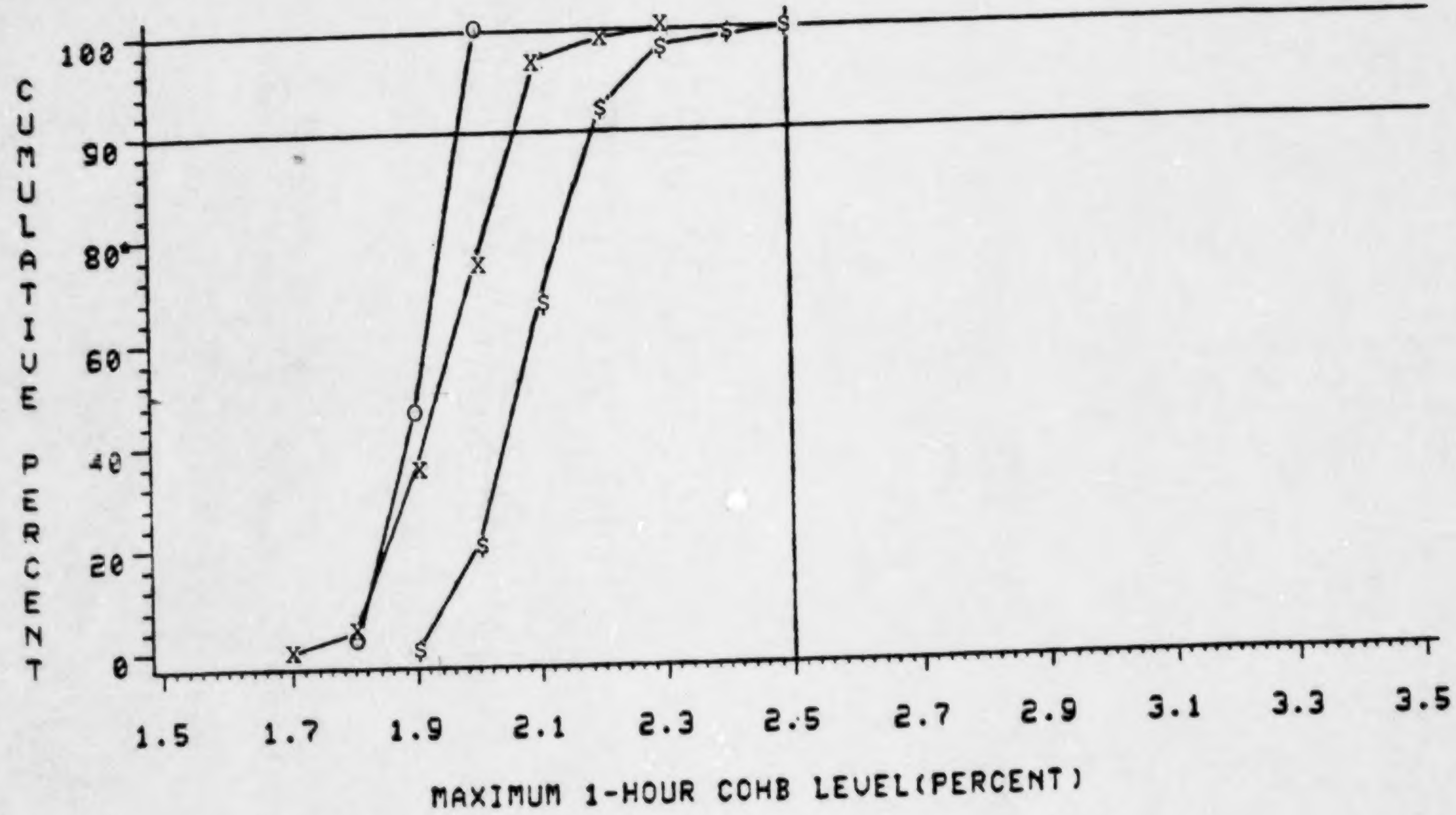
TABLE 5. Cumulative Distribution of Maximum 1-Hour COHb Levels (MlCOHb) of 400 People: Ambient CO Comparison I (Without Microenvironmental Exposures)

MlCOHb (%)	Date 11/24/70	1/2/75	2/11/76
2.5			0.0
2.4			0.50
2.3		0.0	1.00
2.2		0.50	7.25
2.1		2.00	34.00
2.0	0.0	25.50	79.50
1.9	51.25	63.00	100.00
1.8	100.00	96.50	
1.7		100.00	

Altitude=0 ft
V_{CO}=0.007 ml/min
Haldane Constant=230
No microenvironmental CO exposure

FIGURE 6 : MAXIMUM 1-HOUR BLOOD COHB LEVEL

AMBIENT CO PATTERN COMPARISON I



DISTRIBUTION OF MICOHB OF 400 PEOFLE
SHAPE SIMULATION MODEL
ALT=0 FT., UCO=.007 ML/MIN, HALDANE=230
AMBIENT CO ONLY, MICROENVIRONMENTAL CO SET TO ZERO

- * NOTE THE CHANGE IN SCALE

Table 6. Cumulative Distributions of M1AE, MM8AE, and M1COHb of 400 people: Ambient CO Comparison II (With Microenvironmental Exposures)

M1AE (ppm)		Date		MM8AE (ppm)		Date		M1COHb (pct.)		Date	
	11/24/70	1/2/75	2/11/76		11/24/70	1/2/75	2/11/76		11/24/70	1/2/75	2/11/76
36			0	13.5			0	3.3			0
34			.25	13.0			.25	3.2			.25
32			.25	12.5	0	0	1.50	3.1			.25
30			3.75	12.0	.25	.25	7.00	3.0			.75
28			7.25	11.5	.25	.50	26.25	2.9			1.50
26			15.25	11.0	1.50	2.25	88.25	2.8			3.25
24	0	0	71.50	10.5	8.50	14.75	99.75	2.7			8.25
22	.25	.25	100.00	10.0	28.00	88.50	100.00	2.6	0	0	16.25
20	2.75	.75		9.5	96.25	99.50		2.5	.75	.75	29.50
18	6.25	.75		9.0	100.00	100.00		2.4	1.25	5.25	65.50
14	30.25	100.00						2.3	2.50	33.75	89.50
12	100.00							2.2	74.25	74.25	98.25
								2.1	100.00	98.50	100.00
								2.0		100.00	

Altitude= 0 ft, V_{CO}=0.007 ml/min, Haldane Constant=230

Geometric mean and standard deviation of CO concentration in parking garages: mu5=27.56 ppm,
sigma5=1.79

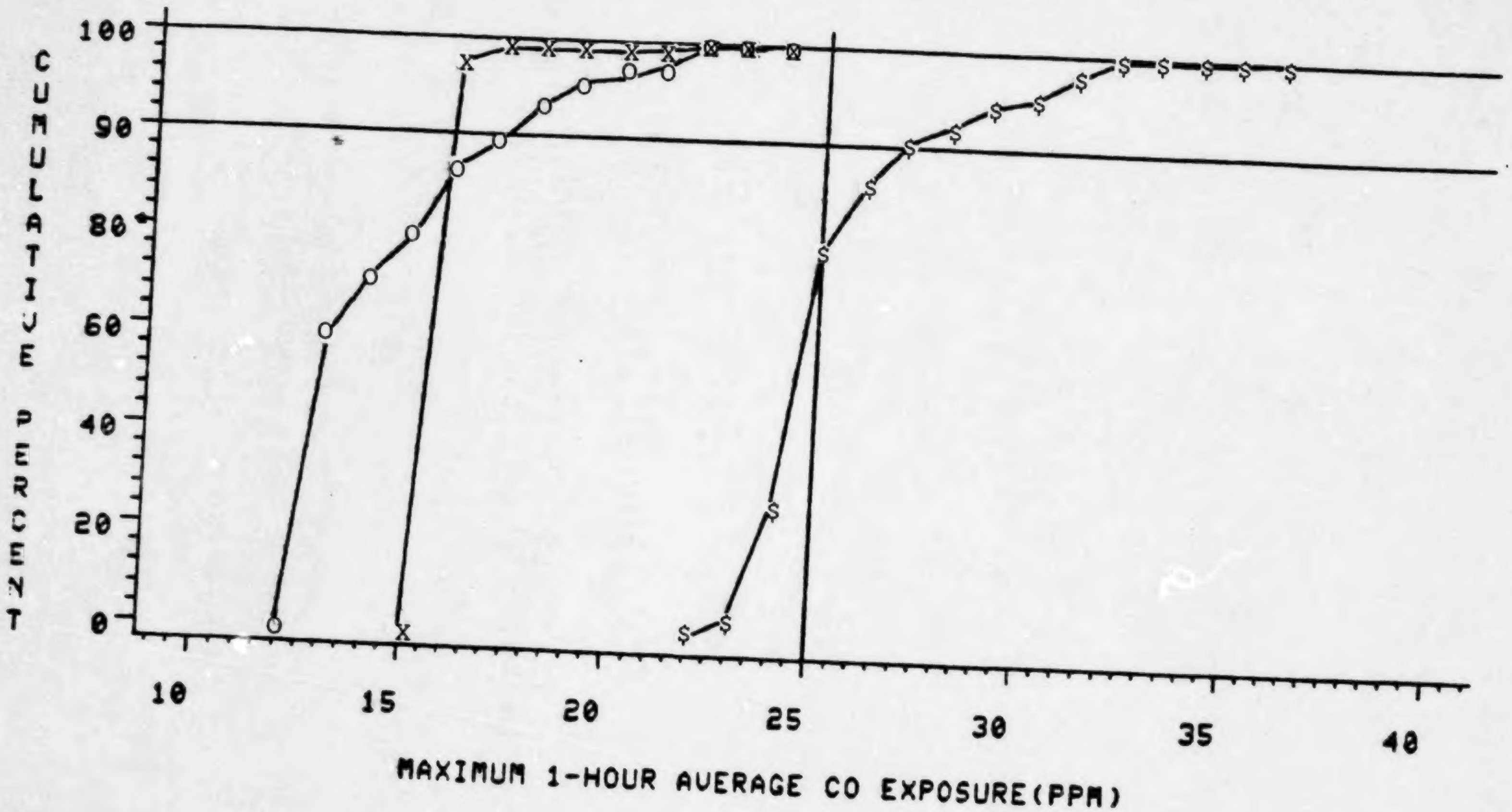
Probability of parking garage use=0.10

Geometric mean and standard deviation of CO concentration in automobiles: mu6=7.8 ppm,
sigma6=2.53

No extra commuting time

FIGURE 7.1: MAXIMUM 1-HOUR AVERAGE CO

AMBIENT CO PATTERN COMPARISON II



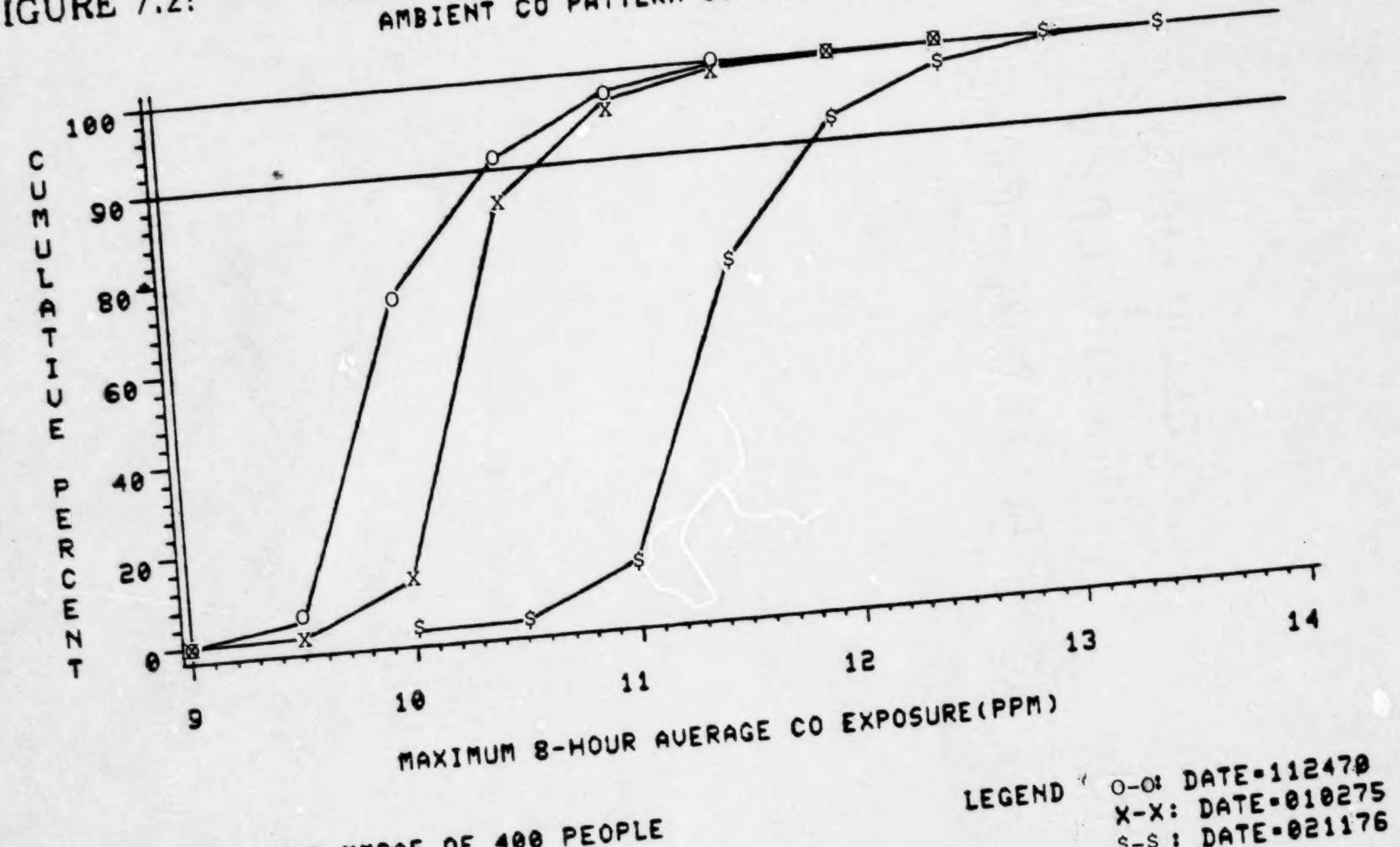
DISTRIBUTION OF M1AE OF 400 PEOPLE
SHAPE SIMULATION MODEL
ALT=0 FT., VCO=.007 ML/MIN, HALDANE=230
MU5=27.56 PPM, GARAGE USE=.10, MU6=7.8 PPM, NO EXTRA COMMUTING TIME

LEGEND
O-O: DATE=112470
X-X: DATE=010275
$-$: DATE=021176

* NOTE THE CHANGE IN SCALE

FIGURE 7.2: MAXIMUM MOVING 8-HOUR AVERAGE CO

AMBIENT CO PATTERN COMPARISON II

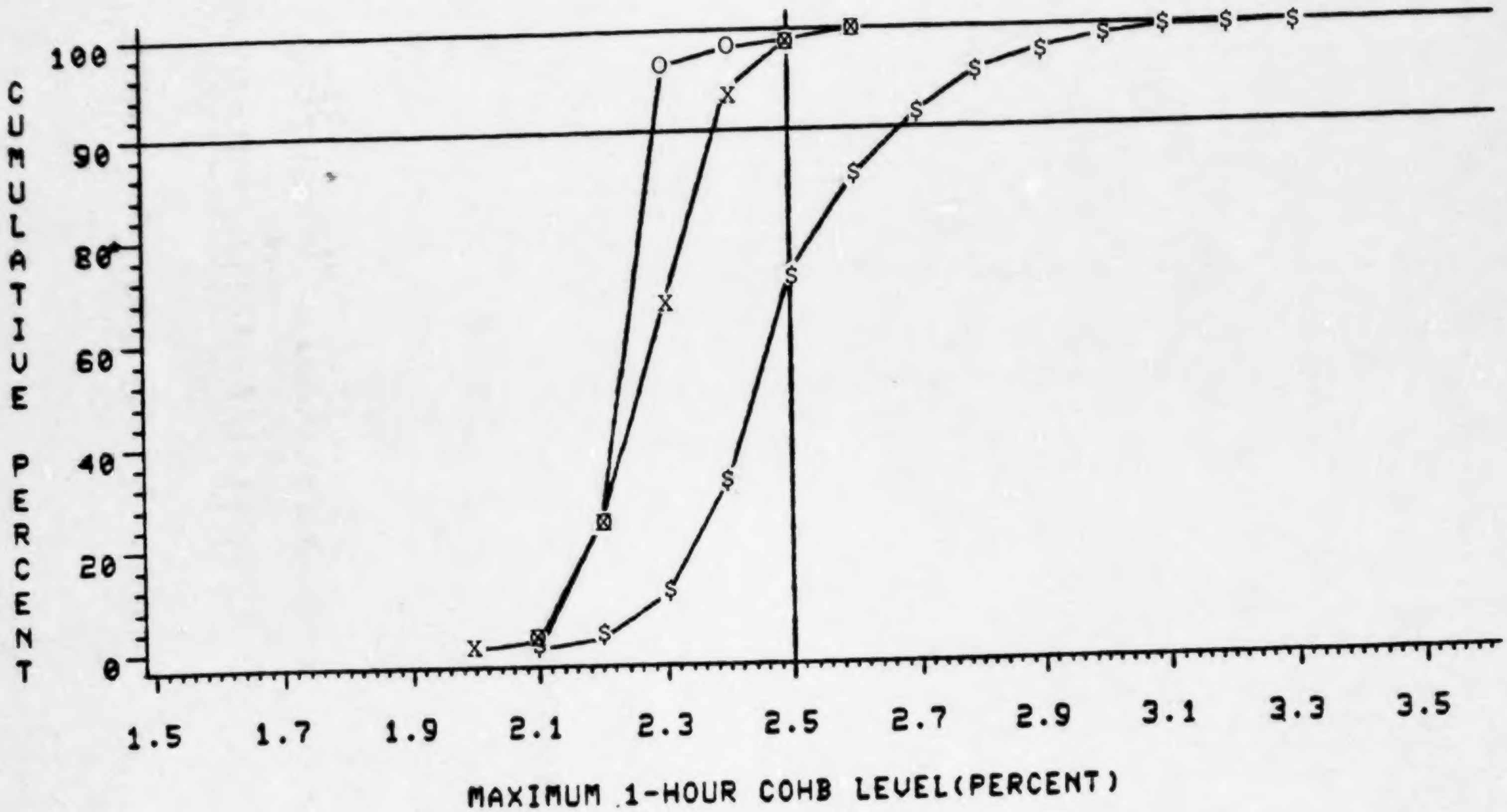


DISTRIBUTION OF MM8AE OF 400 PEOPLE
SHAPE SIMULATION MODEL
ALT=0 FT., VCO=.007 ML/MIN, HALDANE=230
MU5=27.56 PPM, GARAGE USE=.10, MU6=7.8 PPM, NO EXTRA COMMUTING TIME

* NOTE THE CHANGE IN SCALE

FIGURE 7.3: MAXIMUM 1-HOUR BLOOD COHB LEVEL

AMBIENT CO PATTERN COMPARISON II



LEGEND
O-O: DATE•112470
X-X: DATE•010275
$-$: DATE•021176

DISTRIBUTION OF M1COHB OF 400 PEOPLE
SHAPE SIMULATION MODEL
ALT•0 FT., VCO•.007 ML/MIN, HALDANE•230
MU5•27.56 PPM, GARAGE USE•.10, MU6•7.8 PPM, NO EXTRA COMMUTING TIME

* NOTE THE CHANGE IN SCALE

IV. EFFECTS OF PARKING GARAGES AND AUTOMOBILE COMMUTING ON ESTIMATION OF CO EXPOSURE AND BLOOD COHb

To study the impact of the change in microenvironmental CO concentration on the M1AE, MM8AE, and M1COHb estimates, we used two microenvironments - the parking garage (microenvironment 5) and the automobile (microenvironment 6). In the SHAPE program, the microenvironmental 1-minute CO concentrations were assumed to have lognormal distributions, with geometric means and standard deviations estimated from field studies (Appendix A). In the sensitivity analysis, three values of geometric mean and a constant geometric standard deviation were used for both the parking garage and automobile CO concentrations.

Two other parameters, the probability that a commuter uses a parking garage and the extra commuting time used by a commuter, also were considered. Three values of the probability were used, and if a commuter happened to use a parking garage, the time in the garage was fixed at 10 minutes. To account for longer than normal commuting times, 15 or 30 minutes were added to the value sampled from the commuting time distribution. Ziskind, Fite, and Mage (1982) have shown that when the trip duration for a fixed route becomes longer due to increased traffic congestion, traffic volume and CO exposures also increase, but this effect is not modeled here. Three constants used in the Coburn equation were fixed: the altitude at 0 feet, the endogenous CO production rate at 0.007 ml/min, and the Haldane constant at 230. The values used for parking garages and automobile CO concentrations were the limits and midrange from previous studies.

The effects of these two microenvironments were studied separately for all three dates--that is, when the values of parameters associated with parking garages were varied, the values related to automobiles were fixed and vice versa.

To determine the effects of these microenvironmental parameter values on M1AE and MM8AE, we needed only to study their effects on the microenvironmental component of the total CO exposure, since the ambient component is not affected. The individual averages of total microenvironmental CO exposures during a 24-hour period clearly show the effects of the parameters under consideration (Table 7). For each level of the probability of parking garage use, the change in average total microenvironmental CO exposure is very small, as is the change for each level of the geometric mean of CO concentration in parking garages. On the other hand, for automobiles, the change in average total microenvironmental CO exposure is quite large for both parameters associated with automobiles. Thus, the parking garage is insignificant in a person's total CO exposure. The parking garage data also show that changes in maximum exposure and maximum levels of COHb are small (Tables 8, 9 and Figures 8.1, 8.2, 9.1, 9.2). Because the period of exposure in parking garages is assumed to be 10 minutes and the percentage of commuters who use parking garages is low, it is not surprising that changing parking garage parameters has no significant effect.

TABLE 7. Average Total Daily Microenvironmental CO Exposures Associated with Parking Garages and Automobiles (ppm-hours)

Probability of Parking Garage Use	Geometric Mean of CO Concentration in Parking Garages (ppm)			Extra Commuting Time (Min.)	Geometric Mean of CO Concentration in Automobiles (ppm)		
	18.37	27.56	45.94		3.12	7.80	13.16
.01	47.38	47.41	47.46	0	43.77	47.88	52.60
.10	47.61	47.88	48.44	15	46.10	53.10	61.15
.20	48.74	49.25	50.36	30	47.97	57.49	68.43

Sample size=400

Total ambient CO exposure: Nov. 24, 1970=136 ppm-hours
Jan. 2, 1975=115 ppm-hours
Feb. 11, 1976=154 ppm-hours

Altitude=0 ft, $\dot{V}_{CO}$=0.007 ml/min, Haldane Constant=230

TABLE 8: CUMULATIVE DISTRIBUTIONS OF MAXIMUM MOVING 8-HOUR AVERAGE CO EXPOSURE OF 400 PEOPLE FROM SHAPE SIMULATION: PARKING GARAGE CO CONCENTRATION(MUS) (PPM) AND PARKING GARAGE USE COMPARISON

(DATE= FEB. 11, 1976)

MMBAE	USE = .01			USE = .10			USE = .20		
(PPM)	MUS=18.37	MUS=27.56	MUS=45.94	MUS=18.37	MUS=27.56	MUS=45.94	MUS=18.37	MUS=27.56	MUS=45.94
14.0	.	.	.	.	.	0.00	.	.	0.00
13.5	.	.	.	0.00	0.00	0.25	.	0.00	0.25
13.0	0.00	0.00	0.00	0.25	0.25	0.75	0.00	0.25	1.25
12.5	0.75	0.75	0.75	1.25	1.50	4.25	1.75	2.50	5.75
12.0	5.75	5.75	6.00	5.25	7.00	11.00	7.50	10.50	18.50
11.5	26.00	26.00	26.25	25.50	26.25	26.25	33.00	36.25	36.50
11.0	84.75	84.75	84.75	88.25	88.25	88.25	87.75	87.75	87.75
10.5	100.00	100.00	100.00	99.75	99.75	99.75	100.00	100.00	100.00
10.0	.	.	.	100.00	100.00	100.00	.	.	.

ALTITUDE= 0 FT.
ENDOGENOUS CO PRODUCTION RATE= .007 ML/MIN
HALDANE CONSTANT= 230
GEOMETRIC MEAN AND STANDARD DEVIATION OF CO CONCENTRATION IN AUTOMOBILES: MUG=7.80 PPM, SIGMAG=2.53
NO EXTRA COMMUTING TIME

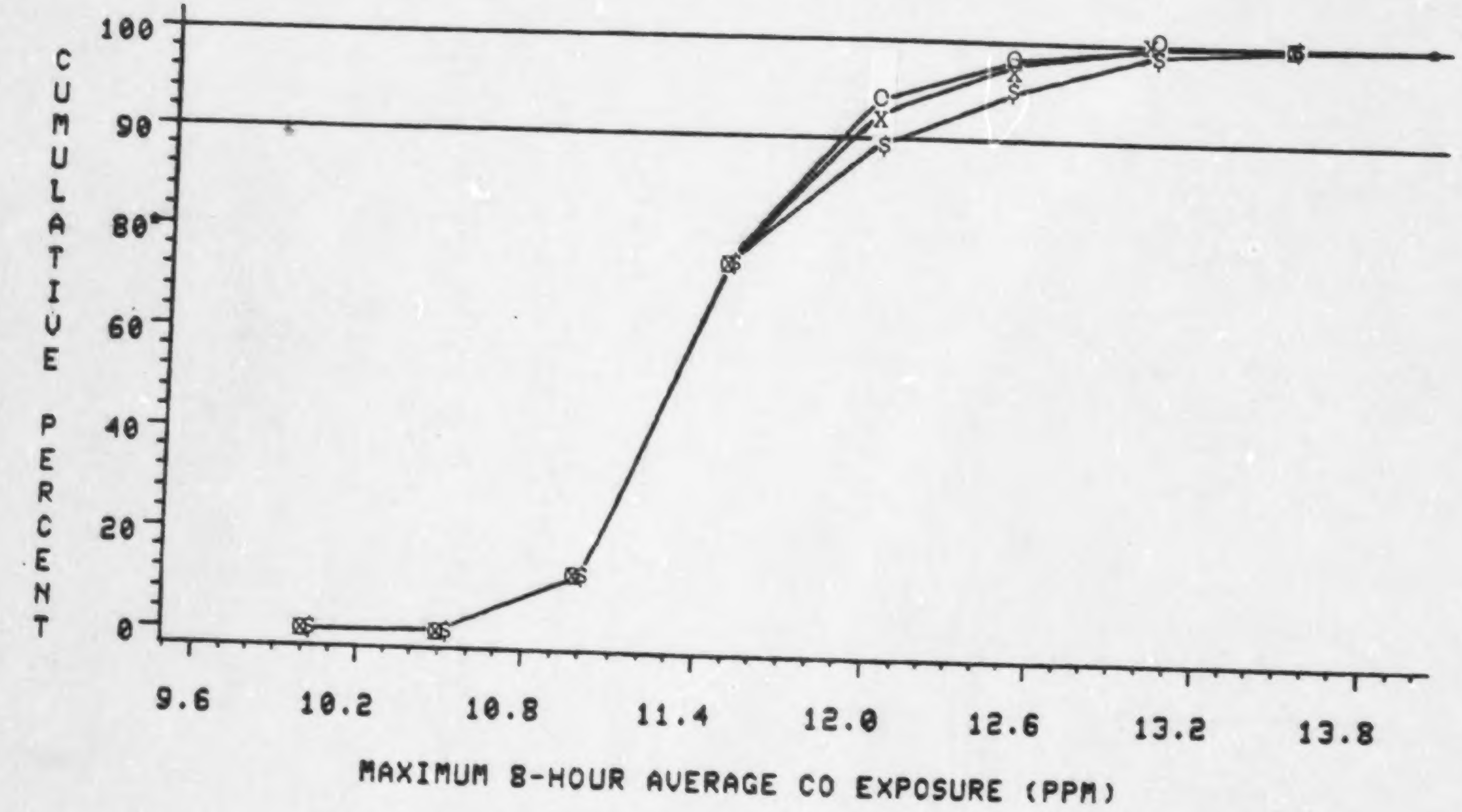
TABLE 9 : CUMULATIVE DISTRIBUTIONS OF MAXIMUM 1-HOUR COHB LEVELS(M1COHB) OF 400 PEOPLE FROM SHAPE SIMULATION;
PARKING GARAGE CO CONCENTRATION(MUS) (PPM) AND PARKING GARAGE USE COMPARISON
(FEB. 11, 1976)

M1COHB	USE = .01			USE = .10			USE = .20		
(PERCENT)	MUS=18.37	MUS=27.56	MUS=45.94	MUS=18.37	MUS=27.56	MUS=45.94	MUS=18.37	MUS=27.56	MUS=45.94
3.4	.	.	.	.	.	0.00	.	.	0.00
3.3	.	.	.	.	0.00	0.25	.	.	0.25
3.2	0.00	0.00	0.00	0.00	0.25	0.25	.	0.00	0.50
3.1	0.25	0.25	0.25	0.25	0.25	0.50	0.00	0.25	1.00
3.0	0.50	0.50	0.50	0.50	0.75	1.50	0.25	0.50	3.00
2.9	0.75	0.75	0.75	1.25	1.50	4.00	1.50	2.25	6.00
2.8	2.25	2.25	2.50	2.75	3.25	6.25	4.50	6.25	11.00
2.7	7.00	7.25	7.25	5.75	8.25	10.00	10.50	12.50	17.75
2.6	15.75	15.75	16.00	15.50	16.25	17.50	20.50	25.00	27.25
2.5	34.50	34.75	35.00	29.00	29.50	30.75	40.50	42.00	43.50
2.4	66.50	66.75	66.75	64.75	65.50	65.75	67.75	68.00	69.00
2.3	87.00	87.00	87.00	89.50	89.50	89.50	89.00	89.25	85.25
2.2	99.00	99.00	99.00	98.25	98.25	98.25	98.75	98.75	98.75
2.1	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00

ALTITUDE= 0 FT.
ENDOGENOUS CO PRODUCTION RATE= .007 ML/MIN
HALDANE CONSTANT= 230
GEOMETRIC MEAN AND STANDARD DEVIATION OF CO CONCENTRATION IN AUTOMOBILES: MUG=7.80 PPM, SIGMAG=2.53
NO EXTRA COMMUTING TIME

FIGURE 8.1: MAXIMUM MOVING 8-HOUR AVERAGE CO

PARKING GARAGE CO COMPARISON



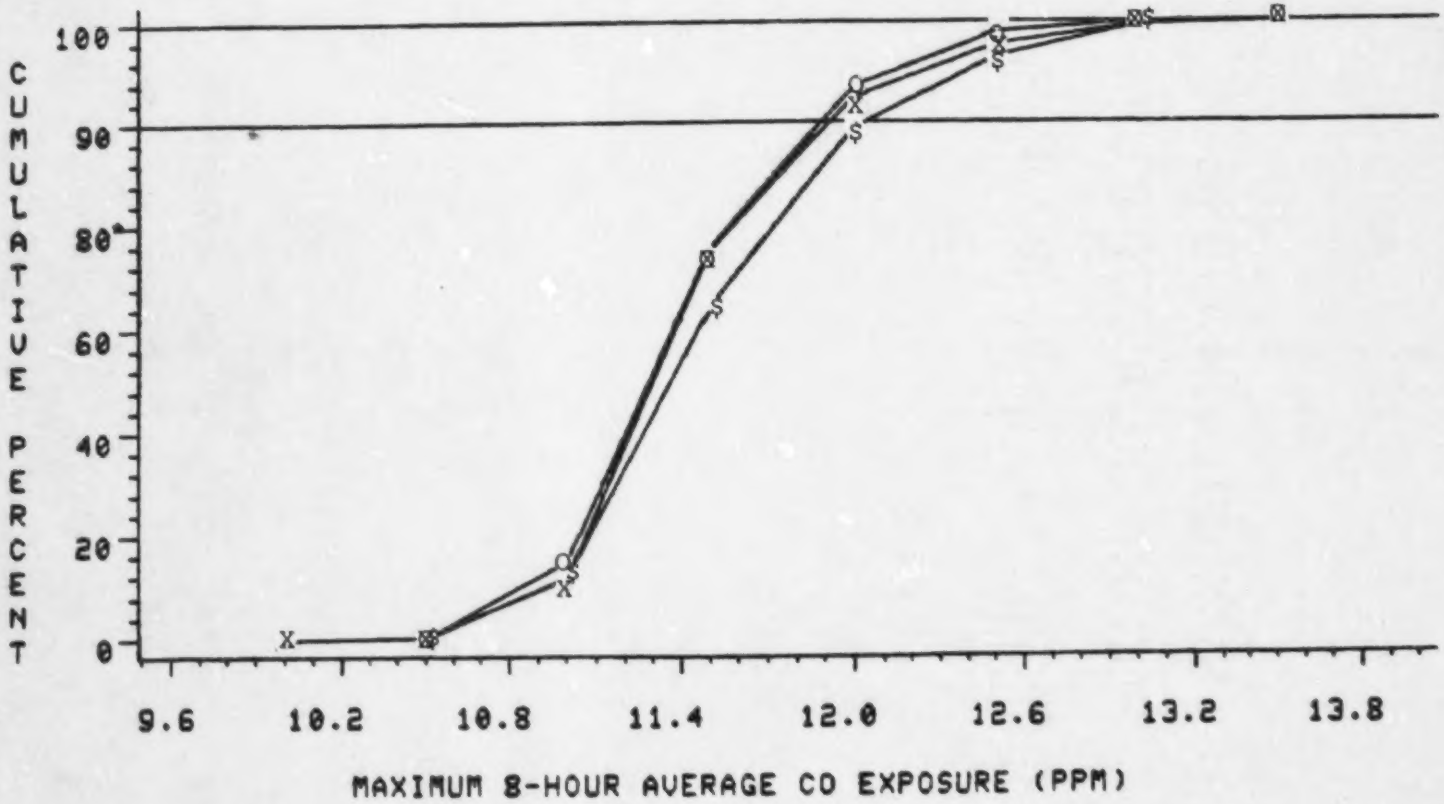
DISTRIBUTION OF MM8AE OF 400 PEOPLE
SHAPE SIMULATION MODEL
DATE=021176, ALT=0 FT., VCO=.007 ML/MIN, HALDANE=230
MU6 =7.8 PPM, NO EXTRA COMMUTING TIME, GARAGE USE=.10

LEGEND O-O : MU5=18.37
X-X: MU5=27.56
$-$: MU5=45.94
(PPM)

* NOTE THE CHANGE IN SCALE

FIGURE 8.2: MAXIMUM MOVING 8-HOUR AVERAGE CO

PARKING GARAGE USE COMPARISON



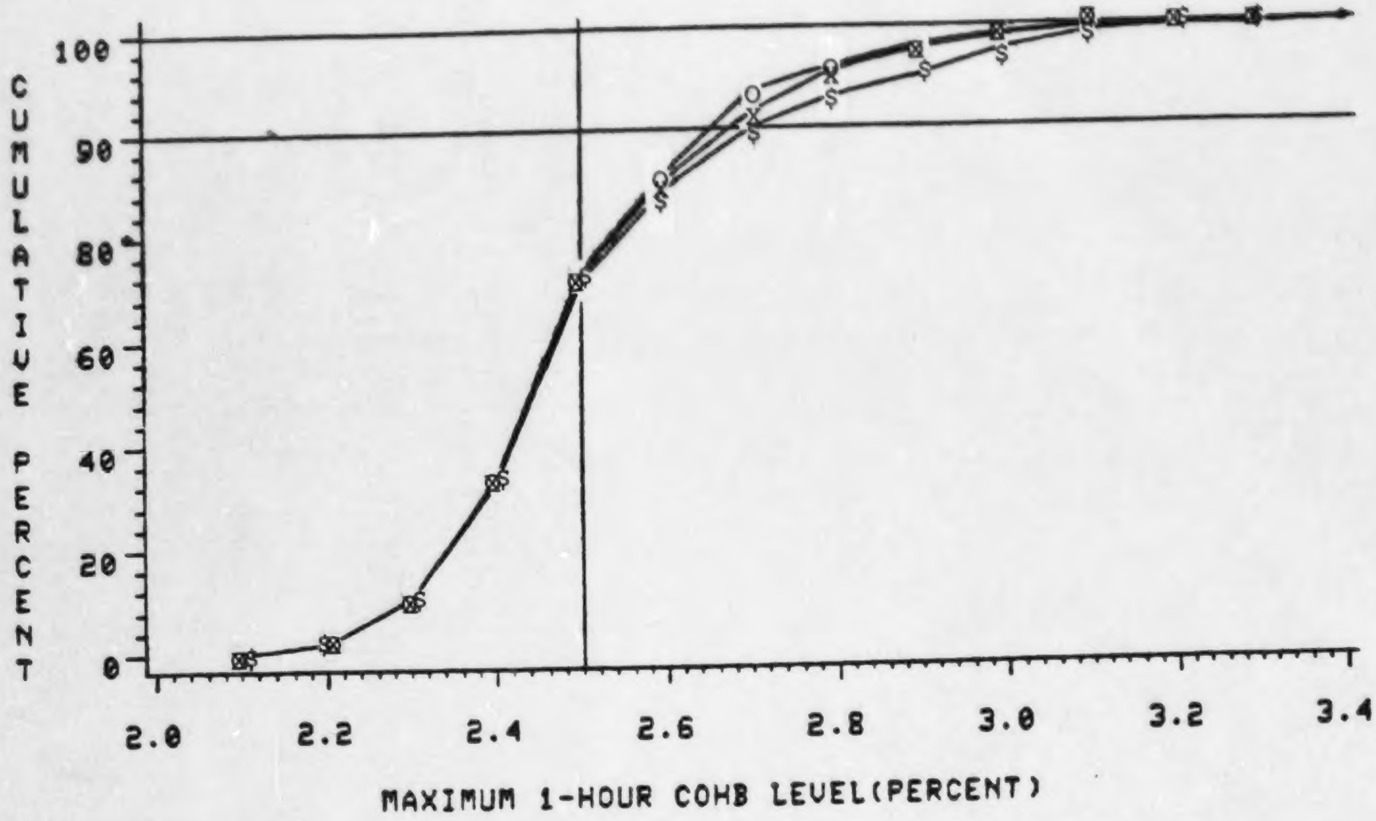
LEGEND O-O : USE=.01
X-X: USE=.10
$-$: USE=.20

DISTRIBUTION OF MM8AE OF 400 PEOPLE
SHAPE SIMULATION MODEL
DATE=021176, ALT=0 FT., VCO=.007 ML/MIN, HALDANE=230
MU5=27.56 PPM, MU6 =7.8 PPM, NO EXTRA COMMUTING TIME

* NOTE THE CHANGE IN SCALE

FIGURE 9.1: MAXIMUM 1-HOUR BLOOD COHB LEVEL

PARKING GARAGE CO COMPARISON



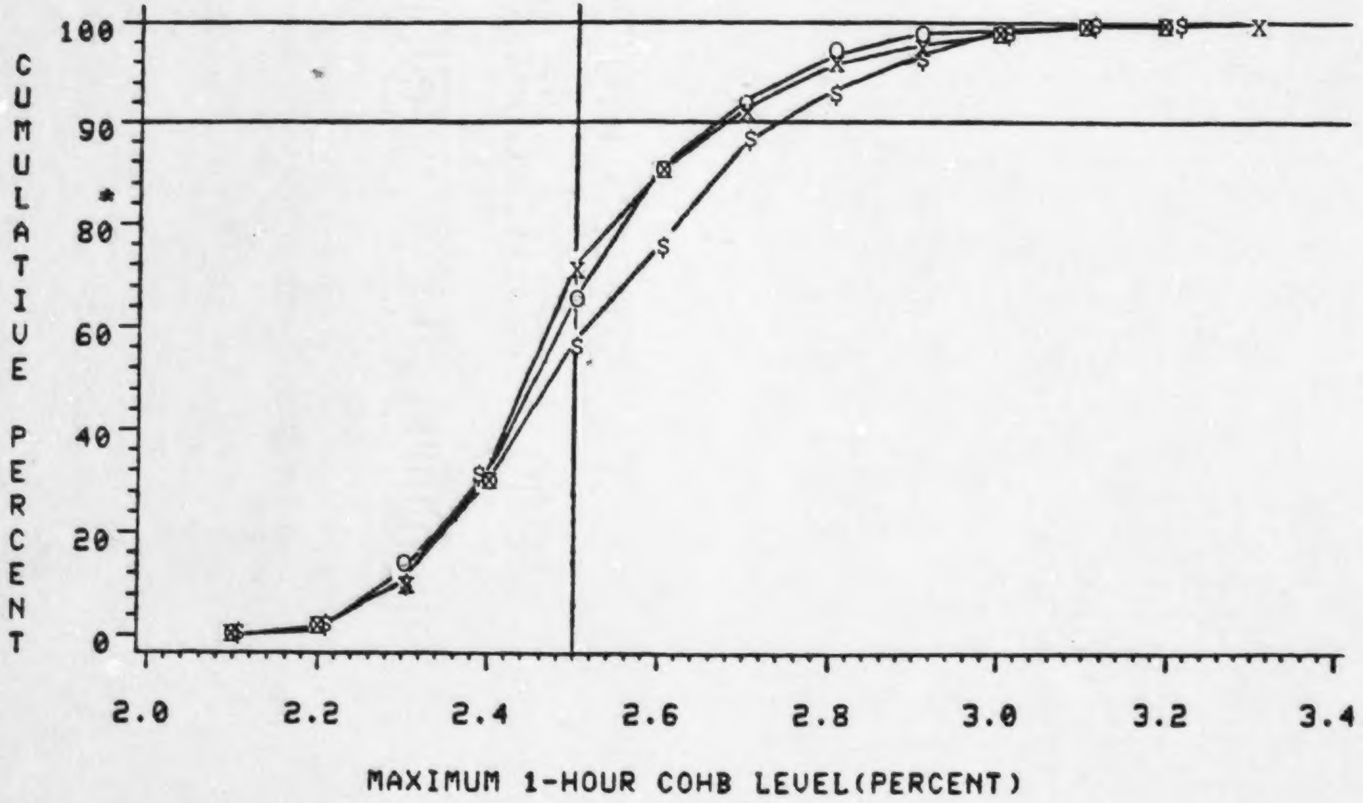
LEGEND O-O : MU5=18.37
X-X: MU5=27.56
$-$: MU5=45.94
(PPM)

DISTRIBUTION OF M1COHB OF 400 PEOPLE
SHAPE SIMULATION MODEL
DATE=021176, ALT=0 FT., VCO=.007 ML/MIN, HALDANE=230
MU6 =7.8 PPM, NO EXTRA COMMUTING TIME, GARAGE USE=.10

* NOTE THE CHANGE IN SCALE

FIGURE 9.2: MAXIMUM 1-HOUR BLOOD COHB LEVEL

PARKING GARAGE USE COMPARISON



DISTRIBUTION OF M1COHB OF 400 PEOPLE
SHAPE SIMULATION MODEL
DATE=021176, ALT=0 FT., UCO=.007 ML/MIN, HALDANE=230
MU5=25.76 PPM, MU6 =7.8 PPM, NO EXTRA COMMUTING TIME

LEGEND O-O: USE=.01
X-X: USE=.10
$-$: USE=.20

* NOTE THE CHANGE IN SCALE

In contrast to the parking garage, the change in parameter values associated with automobiles produced a noticeable change in MM8AE and M1COHb distributions among the 400 people in the simulation (Tables 10, 11). For example, when the geometric mean of CO concentration in automobiles changed from 3.12 to 13.16 ppm, with no extra commuting time, the percentage of people with M1COHb levels of 2.5% and above increased from 15.75% to 46.0% and the percentage above 3.0% COHb increased from 0% to 3.25% COHb. With the geometric mean fixed at 7.8 ppm, the change in extra commuting time from 0 to 30 minutes increased the percentage above 2.5% COHb from 29.50% to 70.75% (Figures 10.1, 10.2, 11.1, 11.2) and the percentage above 3.0% COHb from 0.75% to 3.25%. The analysis of variance result and the arithmetic means clearly indicate the importance of the parameters associated with commuting in automobiles (Table 11.1, 11.2). Since most of the people commuted by automobile (Appendix B), the CO exposure during commuting forms a significant portion of an average person's daily exposure to CO.

Note that SHAPE uses random numbers to generate samples of various distributions in the simulation. If the random number seed is the same, the sample of people by sex, age, height, and hemoglobin content remains the same from one sample to the next. However, varying the probability of using a parking garage or adding extra commuting time caused the sample to vary. For each level of probability and for each level of extra commuting time, the samples are the same. Also, note that the effect of the extra commuting time depends upon the ambient CO concentration pattern. If the ambient CO exposures are low during commuting hours, as they were on Jan. 2, 1975, the maximum COHb does not occur during those hours, and the M1COHb distribution will not reflect the extra commuting time.

TABLE 10: CUMULATIVE DISTRIBUTIONS OF MAXIMUM MOVING 8-HOUR AVERAGE CO EXPOSURE OF 400 PEOPLE FROM SHAPE SIMULATION
AUTOMOBILE CO CONCENTRATION(MUG) (PPM) AND EXTRA COMMUTING TIME (MINUTES) COMPARISON
(DATE= FEB. 11, 1976)

MMBAE	EXTRA = 0			EXTRA = 15			EXTRA = 30		
(PPM)	MUG=3.12	MUG=7.80	MUG=13.16	MUG=3.12	MUG=7.80	MUG=13.16	MUG=3.12	MUG=7.80	MUG=13.16
17.0	.	.	.	.	.	.	.	.	0.00
16.5	.	.	.	.	.	.	.	.	0.25
16.0	.	.	.	.	.	.	.	.	0.25
15.5	.	.	.	.	.	.	.	.	0.75
15.0	.	.	0.00	.	.	0.00	.	.	1.25
14.5	.	.	0.25	.	.	0.25	.	0.00	1.75
14.0	.	.	0.75	.	.	1.75	.	0.25	3.75
13.5	.	0.00	1.50	.	.	4.50	0.00	0.75	9.25
13.0	.	0.25	4.25	0.00	0.00	9.50	0.25	2.25	26.00
12.5	0.00	1.50	7.50	0.75	4.00	24.75	0.75	9.25	49.25
12.0	0.75	7.00	19.50	4.00	21.00	54.25	6.25	38.00	79.75
11.5	11.25	26.25	43.25	18.50	61.50	85.50	28.25	90.25	96.50
11.0	72.50	88.25	93.25	87.75	96.25	96.75	92.00	98.50	98.50
10.5	99.75	99.75	99.75	100.00	100.00	100.00	100.00	100.00	100.00
10.0	100.00	100.00	100.00	.	.	.	.	.	.

ALTITUDE= 0 FT.
ENDOGENOUS CO PRODUCTION RATE= .007 ML/MIN
HALDANE CONSTANT= 230
GEOMETRIC MEAN AND STANDARD DEVIATION OF CO CONCENTRATION IN PARKING GARAGES: MUS=27.56 PPM, SIGMAS=1.79
PROBABILITY OF USING PARKING GARAGE= .10

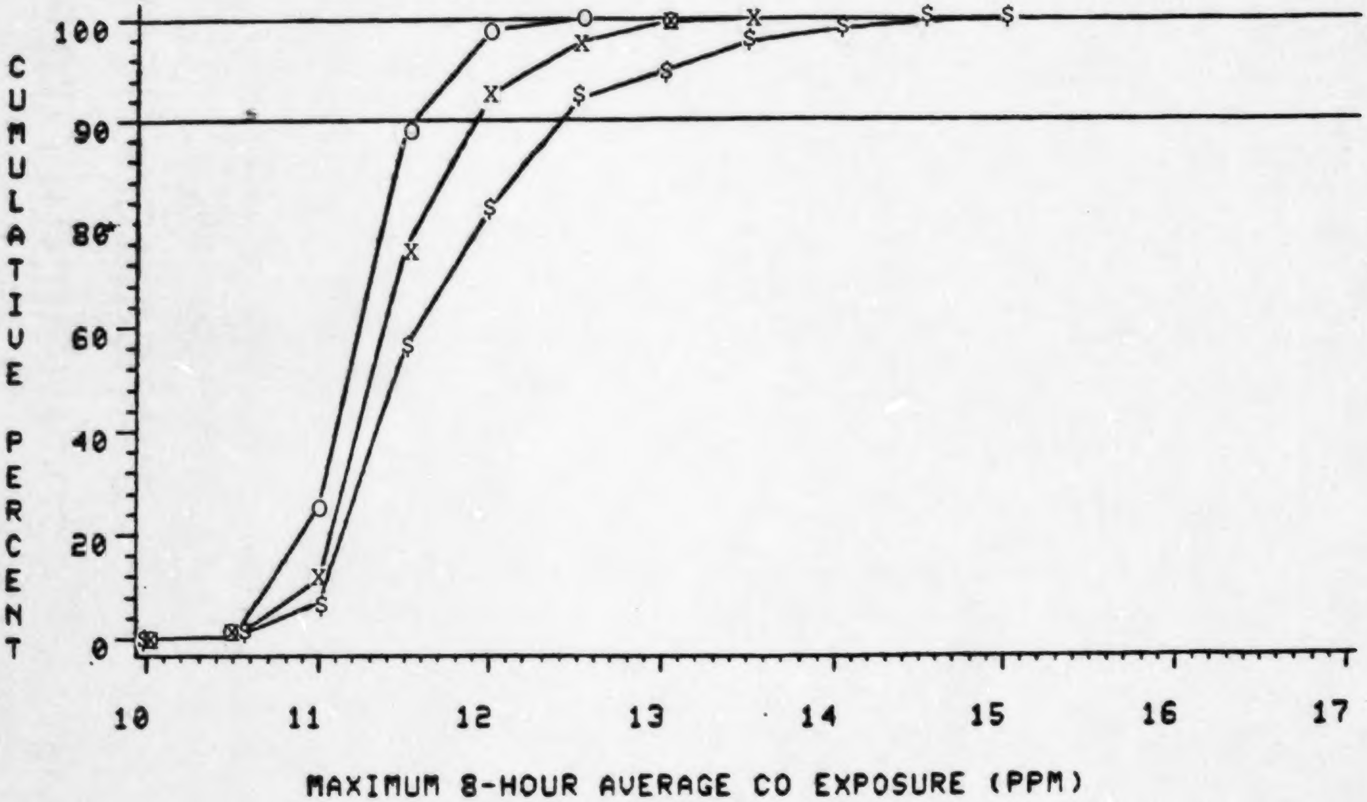
TABLE 11 : CUMULATIVE DISTRIBUTIONS OF MAXIMUM 1-HOUR COHB LEVELS(M1COHB) OF 400 PEOPLE FROM SHAPE SIMULATION
AUTOMOBILE CO CONCENTRATION(MU6) (PPM) AND EXTRA COMMUTING TIME (MINUTES) COMPARISON
(DATE• FEB. 11, 1976)

M1COHB	EXTRA • 0			EXTRA • 15			EXTRA • 30		
(PERCENT)	MU6•3.12	MU6•7.80	MU6•13.16	MU6•3.12	MU6•7.80	MU6•13.16	MU6•3.12	MU6•7.80	MU6•13.16
4.0	.	.	.	.	.	.	.	.	0.00
3.9	.	.	.	.	.	.	.	.	0.25
3.8	.	.	.	.	.	.	.	.	0.50
3.7	.	.	0.00	.	.	.	.	.	0.75
3.6	.	.	0.25	.	.	.	.	.	0.75
3.5	.	.	0.25	.	.	0.00	.	.	1.50
3.4	.	.	0.75	.	.	0.50	.	0.00	2.75
3.3	.	0.00	1.00	.	.	1.00	.	0.25	5.75
3.2	.	0.25	1.50	.	0.00	2.25	0.00	1.00	9.75
3.1	.	0.25	2.25	.	0.25	4.75	0.25	1.75	14.75
3.0	.	0.75	3.25	.	0.75	7.50	0.75	3.75	22.00
2.9	0.00	1.50	5.75	0.00	1.75	15.00	1.75	9.00	31.50
2.8	0.50	3.25	11.00	1.25	6.50	27.00	2.50	16.25	44.75
2.7	3.75	8.25	17.50	4.50	15.25	41.00	7.50	27.75	60.00
2.6	8.00	16.25	29.25	10.00	34.25	59.50	17.75	47.25	74.75
2.5	15.75	29.50	46.00	25.25	56.50	75.50	34.75	70.75	87.00
2.4	48.75	65.50	74.75	57.00	78.50	89.50	63.00	90.00	96.00
2.3	81.50	89.50	92.75	84.00	95.75	97.25	89.25	97.50	99.25
2.2	96.75	98.25	98.75	98.50	100.00	100.00	98.50	99.50	99.50
2.1	100.00	100.00	100.00	100.00	.	.	100.00	100.00	100.00

ALTITUDE• 0 FT.
ENDOGENOUS CO PRODUCTION RATE• .007 ML/MIN
HALDANE CONSTANT• 230
GEOMETRIC MEAN AND STANDARD DEVIATION OF CO CONCENTRATION IN PARKING GARAGES: MU5•27.56 PPM, SIGMA5•1.70
PROBABILITY OF USING PARKING GARAGE• .10

FIGURE 10.1: MAXIMUM MOVING 8-HOUR AVERAGE CO

AUTOMOBILE CO COMPARISON



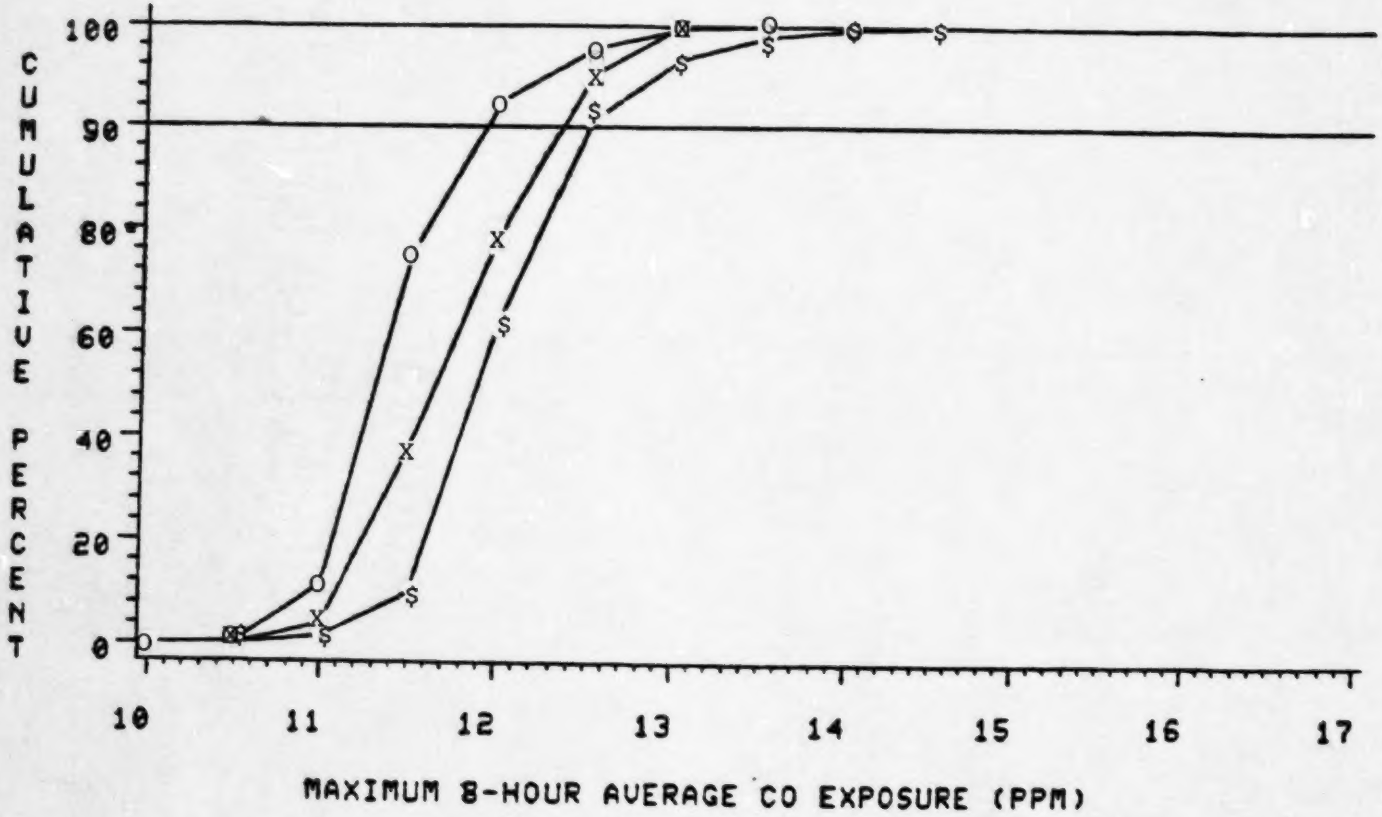
DISTRIBUTION OF MM8AE OF 400 PEOPLE
SHAPE SIMULATION MODEL
DATE=021176, ALT=0 FT., UCO=.007 ML/MIN, HALDANE=230
MU5=27.56 PPM, GARAGE USE=.10, NO EXTRA COMMUTING TIME

LEGEND O-O : MU6= 3.12
X-X: MU6= 7.80
$-$: MU6=13.16
(PPM)

* NOTE THE CHANGE IN SCALE

FIGURE 10.2: MAXIMUM MOVING 8-HOUR AVERAGE CO

EXTRA COMMUTING TIME COMPARISON



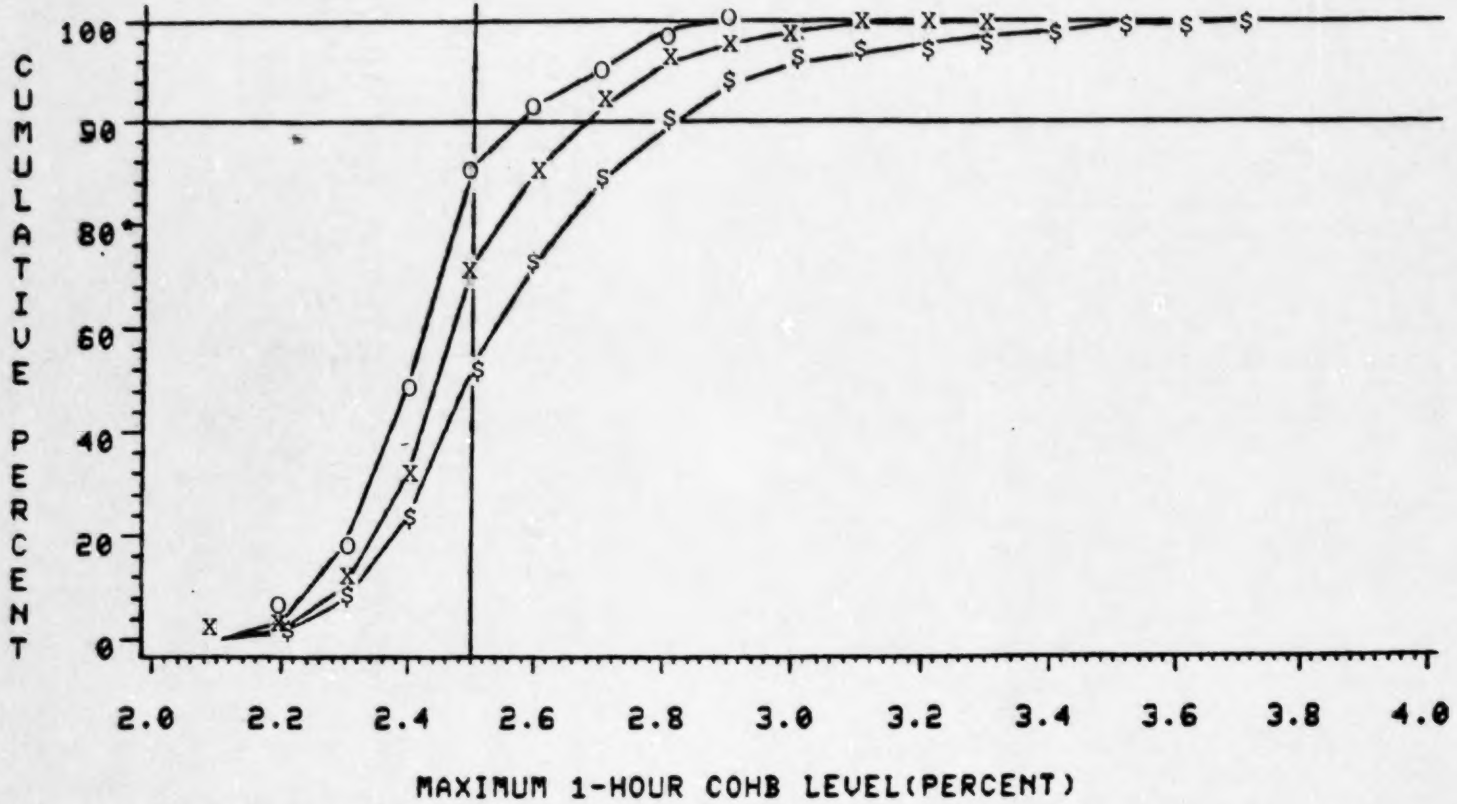
DISTRIBUTION OF MM8AE OF 400 PEOPLE
SHAPE SIMULATION MODEL
DATE=021176, ALT=0 FT., VCO=.007 ML/MIN, HALDANE=230
MU5=27.56 PPM, GARAGE USE=.10, MU6=7.80 PPM

LEGEND
O-O: TIME= 0
X-X: TIME= 15
$-$: TIME= 30
(MIN)

* NOTE THE CHANGE IN SCALE

FIGURE 11.1: MAXIMUM 1-HOUR BLOOD COHB LEVEL

AUTOMOBILE CO COMPARISON



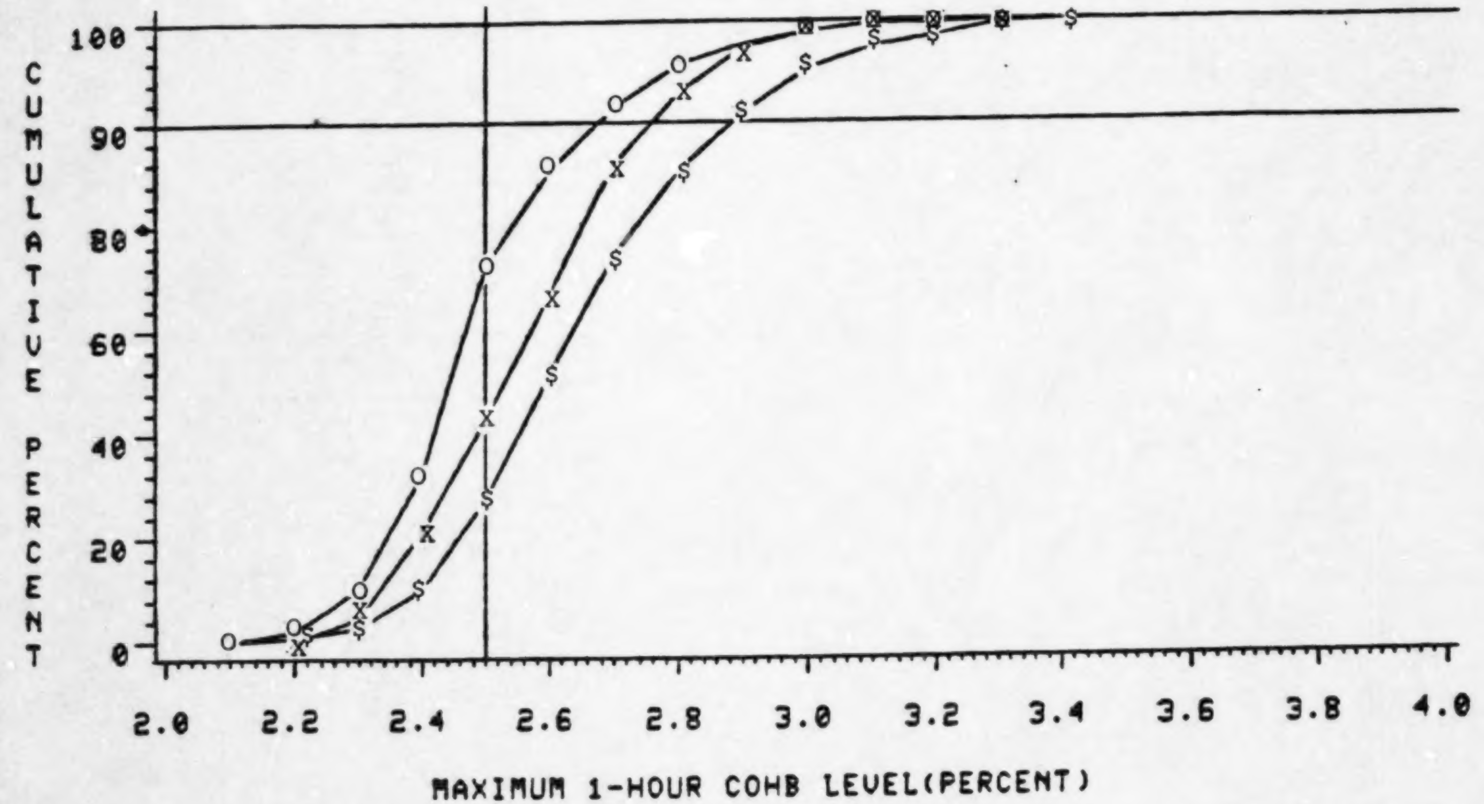
DISTRIBUTION OF M1COHB OF 400 PEOPLE
SHAPE SIMULATION MODEL
DATE=021176, ALT=0 FT., UCO=.007 ML/MIN, HALDANE=230
MUS=27.56 PPM, GARAGE USE=.10, NO EXTRA COMMUTING TIME

LEGEND O-O: MUG= 3.12
X-X: MUG= 7.80
$-$: MUG=13.16
(PPM)

* NOTE THE CHANGE IN SCALE

FIGURE 11.2: MAXIMUM 1-HOUR BLOOD COHB LEVEL

EXTRA COMMUTING TIME COMPARISON



DISTRIBUTION OF M1COHB OF 400 PEOPLE
SHAPE SIMULATION MODEL
DATE=021176, ALT=0 FT., VCO=.007 ML/MIN, HALDANE=230
MU5=27.56 PPM, GARAGE USE=.10, MU6=7.80 PPM

LEGEND O-O : TIME= 0
X-X: TIME= 15
$-$: TIME= 30
(MIN)

* NOTE THE CHANGE IN SCALE

TABLE 11.1. Arithmetic Means and Standard Deviations of Maximum 1-Hour Blood COHb Levels (Percent) of 400 People:

Parking Garage CO Concentration and Parking Garage Use

Parking Garage Use	Geometric Mean of CO Concentration in Parking Garages (ppm)		
	18.37	27.56	45.94
.01	2.461 (.149)	2.461 (.149)	2.462 (.150)
.10	2.458 (.145)	2.463 (.154)	2.475 (.177)
.20	2.482 (.162)	2.492 (.174)	2.516 (.207)

p-value: Both main effects, .0001
Interaction effects, .0112

Date: Feb. 11, 1976

$\dot{V}_{CO}$ = 0.007 ml/min

Haldane Constant = 230

Geometric mean and standard deviation of CO concentration in automobiles: mu6=7.8 ppm, sigma6=2.53

No extra commuting time

TABLE 11.2. Arithmetic Means and Standard Deviations of Maximum 1-hour COHb Levels (Percent) of 400 People:

Automobile CO Concentration and Extra Commuting Time

Extra Commuting Time (Minutes)	Geometric Mean of CO Concentration in Automobiles (ppm)		
	3.12	7.80	13.16
0	2.405 (.124)	2.463 (.154)	2.535 (.212)
15	2.429 (.130)	2.537 (.160)	2.669 (.227)
30	2.466 (.152)	2.618 (.193)	2.801 (.282)

p-values: Both main effects and interaction effect, .0001

Date: Feb. 11, 1976
Altitude = 0 ft.
V_{CO} = 0.007 ml/min
Haldane Constant = 230
Geometric mean and standard deviation of CO concentration in parking garage: mu5 = 27.56 ppm, sigma6 = 1.79
Probability of using parking garage = 0.10

V. EFFECTS OF ALTITUDE, ENDOGENOUS CO PRODUCTION, AND HALDANE CONSTANT ON ESTIMATION OF BLOOD COHb

To study the effects of altitude (barometric pressure) in the Coburn equation (as derived) in the estimation of blood COHb, SHAPE was run using two altitudes (0 and 5280 feet), three endogenous CO production rates (0.007, 0.010, and 0.015 ml/min), and three Haldane parameters (210, 230, and 250). The first altitude corresponds to that of Washington, D.C., and the second to Denver, Colo. Field studies on CO exposures have been performed in both cities. For each altitude, there are nine combinations of these endogenous CO production rates and Haldane parameters. The values used for these two parameters covered the ranges used in the literature (Biller and Richmond, 1982). Note that since these three parameters were used only in the Coburn equation in estimating blood COHb from CO exposures, there are no changes in distributions of M1AE and MM8AE when the values of these parameters are changed. For these runs, the values of those parameters studied in Section IV were fixed: geometric mean of CO concentration in parking garages at 27.6 ppm, probability of parking garage use at 0.10, geometric mean of CO concentration in automobiles at 7.8 ppm, and extra commuting time at zero.

It is well known that the endogenous CO rates (V_{CO}) and the Haldane constant (M) are important factors in estimating blood COHb (Peterson and Stewart, 1975). For example, when the altitude was set at zero and the Haldane constant at 230, adjusting the endogenous CO production rate from 0.007 to 0.015 ml/min caused the percentage of people with M1COHb 2.5% and above to increase from 29.5% to 87% (Table 12.1, Figure 12.2). If 3.0% is considered to be the critical level of M1COHb, the increase in the proportion of population above 3% COHb is from 0.75% to 3.0% (Table 12.1, Figure 12.2). Similarly, when the altitude was set at zero and the endogenous production rate at 0.007 ml/min, resetting the Haldane constant from 210 to 250 increased the percentage of people with M1COHb 2.5% and above from 10% to 80.5% (Table 12.1, Figure 12.3). If 3.0% is considered the criteria level, the change in the proportion of the population above 3% COHb due to the Haldane constant will be only from 0.25% to 0.75%. When taken together, variations in the endogenous CO production rate and Haldane constant can exert a significant effect on the number of people experiencing high M1COHb levels (Table 12.3).

The effect of increasing altitude, or, more correctly, decreasing barometric pressure (P_B), appears in the Coburn-Forster-Kane (CFK) equation (Appendix C) as a reduction of the partial pressure of oxygen in the alveolar region and as a reduction of the CO tension in the inspired air. The combined effect of barometric pressure on these two partial pressures in the CFK equation produces a change in COHb as demonstrated by comparing results at sea level (Table 12.1) and at 5280 feet (Table 12.2). The cumulative frequency distribution for these two elevations differ significantly (Figure 12.1). For example, on Feb. 11, 1976, the endogenous CO production rate was fixed at 0.007 ml/min and the Haldane constant was fixed at 230, but the change in altitude caused the percentage of people with M1COHb 2.5% and above to increase from 29.5% to

```
TABLE 12.1: CUMULATIVE DISTRIBUTIONS OF MAXIMUM 1-HOUR COHB LEVELS(MICOHB) OF 400 PEOPLE FROM SHAPE SIMULATION
          ENDOGENOUS CO PRODUCTION RATE(UCO) (ML/MIN) AND HALDANE CONSTANT COMPARISON
          (DATE= FEB. 11, 1976   ALTITUDE=    0 FT.)
------------------------------------------------------------------------------------------------------------
  MICOHB             HALDANE 210                     HALDANE 230                     HALDANE 250
                     -----------                     -----------                     -----------
 (PERCENT)    UCO=.007  UCO=.010  UCO=.015    UCO=.007  UCO=.010  UCO=.015    UCO=.007  UCO=.010  UCO=.015
              ----------------------------    ----------------------------    ----------------------------
   3.6            .         .         .           .         .         .           .         .        0.00
   3.5            .         .         .           .         .         .           .        0.00      0.50
   3.4            .         .         .           .         .        0.00        0.00      0.25      0.75
   3.3            .         .         .          0.00      0.00      0.50        0.25      0.75      1.50
   3.2            .         .        0.00        0.25      0.25      0.75        0.75      1.25      3.25
   3.1           0.00      0.00      0.25        0.25      0.75      1.50        1.25      2.00      7.75
   3.0           0.25      0.25      0.75        0.75      1.50      3.00        2.75      5.75     14.50
   2.9           0.25      0.75      1.50        1.50      2.75      7.75        6.50     11.50     27.25
   2.8           0.75      1.50      3.00        3.25      7.00     15.75       13.75     21.25     52.75
   2.7           1.50      3.00      8.50        8.25     14.50     31.75       24.75     41.50     80.50
   2.6           4.75      8.00     18.00       16.25     26.50     64.50       46.00     73.75     95.00
   2.5          10.00     16.50     37.75       29.50     54.75     87.00       80.50     93.00     99.50
   2.4          19.25     32.50     71.25       65.50     84.25     97.50       95.00     99.00    100.00
   2.3          40.75     69.00     92.25       89.50     96.75    100.00       99.75    100.00       .
   2.2          76.50     92.25     99.00       98.25    100.00       .        100.00       .         .
   2.1          95.25     99.00    100.00      100.00       .         .           .         .         .
   2.0          99.75    100.00       .           .         .         .           .         .         .
   1.9         100.00       .         .           .         .         .           .         .         .
------------------------------------------------------------------------------------------------------------
GEOMETRIC MEAN AND STANDARD DEVIATION OF CO CONCENTRATION IN PARKING GARAGES: MU5=27.56 PPM, SIGMA5=1.79
PROBABILITY OF USING PARKING GARAGE= .10
GEOMETRIC MEAN AND STANDARD DEVIATION OF CO CONCENTRATION IN AUTOMOBILES: MU6=7.80 PPM, SIGMA6=2.53
NO EXTRA COMPUTING TIME
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TABLE 12.2: CUMULATIVE DISTRIBUTIONS OF MAXIMUM 1-HOUR COHB LEVELS(M1COHB) OF 400 PEOPLE FROM SHAPE SIMULATION

ENDOGENOUS CO PRODUCTION RATE(UCO)_(ML/MIN) AND HALDANE CONSTANT COMPARISON

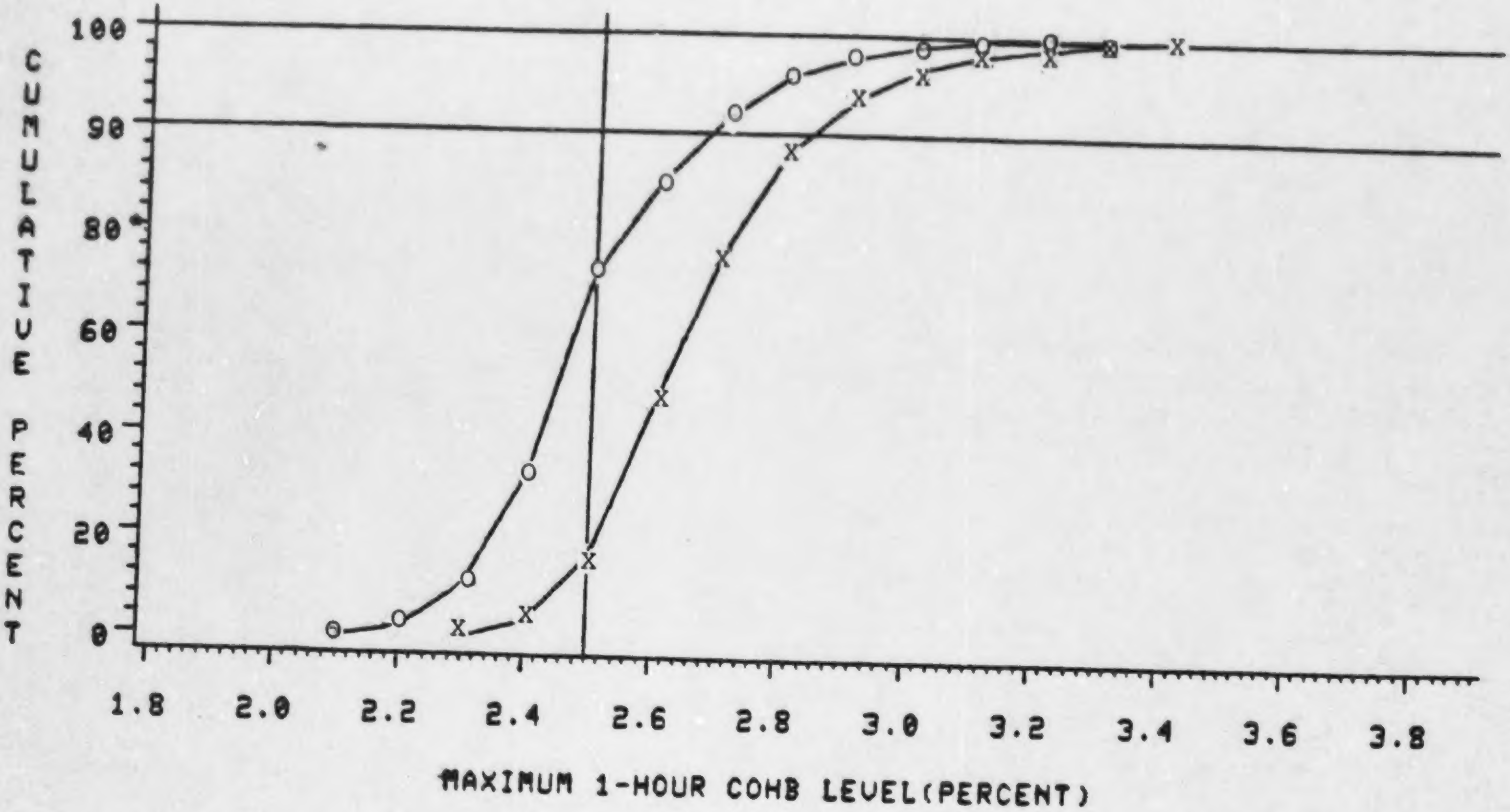
(DATE= FEB. 11, 1976   ALTITUDE= 5280 FT.)

M1COHB	HALDANE 210			HALDANE 230			HALDANE 250		
(PERCENT)	UCO=.007	UCO=.010	UCO=.015	UCO=.007	UCO=.010	UCO=.015	UCO=.007	UCO=.010	UCO=.015
3.9	.	.	.	.	.	.	.	.	0.00
3.8	.	.	.	.	.	.	.	.	0.25
3.7	.	.	.	.	.	.	.	0.00	0.50
3.6	.	.	.	.	.	0.00	0.00	0.25	1.00
3.5	.	.	.	.	0.00	0.50	0.25	0.75	2.25
3.4	.	.	0.00	0.00	0.25	0.75	0.75	1.25	4.00
3.3	.	0.00	0.50	0.25	0.75	1.75	1.25	2.25	9.25
3.2	0.00	0.25	0.75	0.75	1.25	4.00	2.25	5.50	16.25
3.1	0.25	0.50	1.50	1.25	2.25	9.50	5.50	10.75	31.75
3.0	0.75	1.25	3.25	2.25	5.50	16.50	10.75	21.00	59.25
2.9	1.25	2.25	8.75	6.00	12.25	34.25	21.00	40.75	84.50
2.8	2.50	6.50	17.00	12.50	24.00	65.75	40.75	71.75	95.50
2.7	7.00	14.25	35.00	25.00	47.00	87.00	73.50	91.50	99.75
2.6	14.50	26.25	69.75	51.00	80.50	98.00	93.00	98.75	100.00
2.5	27.75	56.25	85.50	83.50	95.00	100.00	99.00	100.00	.
2.4	63.25	84.75	98.75	96.75	99.75	.	100.00	.	.
2.3	89.50	97.50	100.00	100.00	100.00	.	.	.	.
2.2	98.75	100.00	.	.	.	.	.	.	.
2.1	100.00	.	.	.	.	.	.	.	.

GEOMETRIC MEAN AND STANDARD DEVIATION OF CO CONCENTRATION IN PARKING GARAGES: MUS=27.56 PPM, SIGMAS=1.79
PROBABILITY OF USING PARKING GARAGE= .10
GEOMETRIC MEAN AND STANDARD DEVIATION OF CO CONCENTRATION IN AUTOMOBILES: MUG=7.80 PPM, SIGMAG=2.53
NO EXTRA COMMUTING TIME

FIGURE 12.1: MAXIMUM 1-HOUR BLOOD COHB LEVEL

ALTITUDE COMPARISON



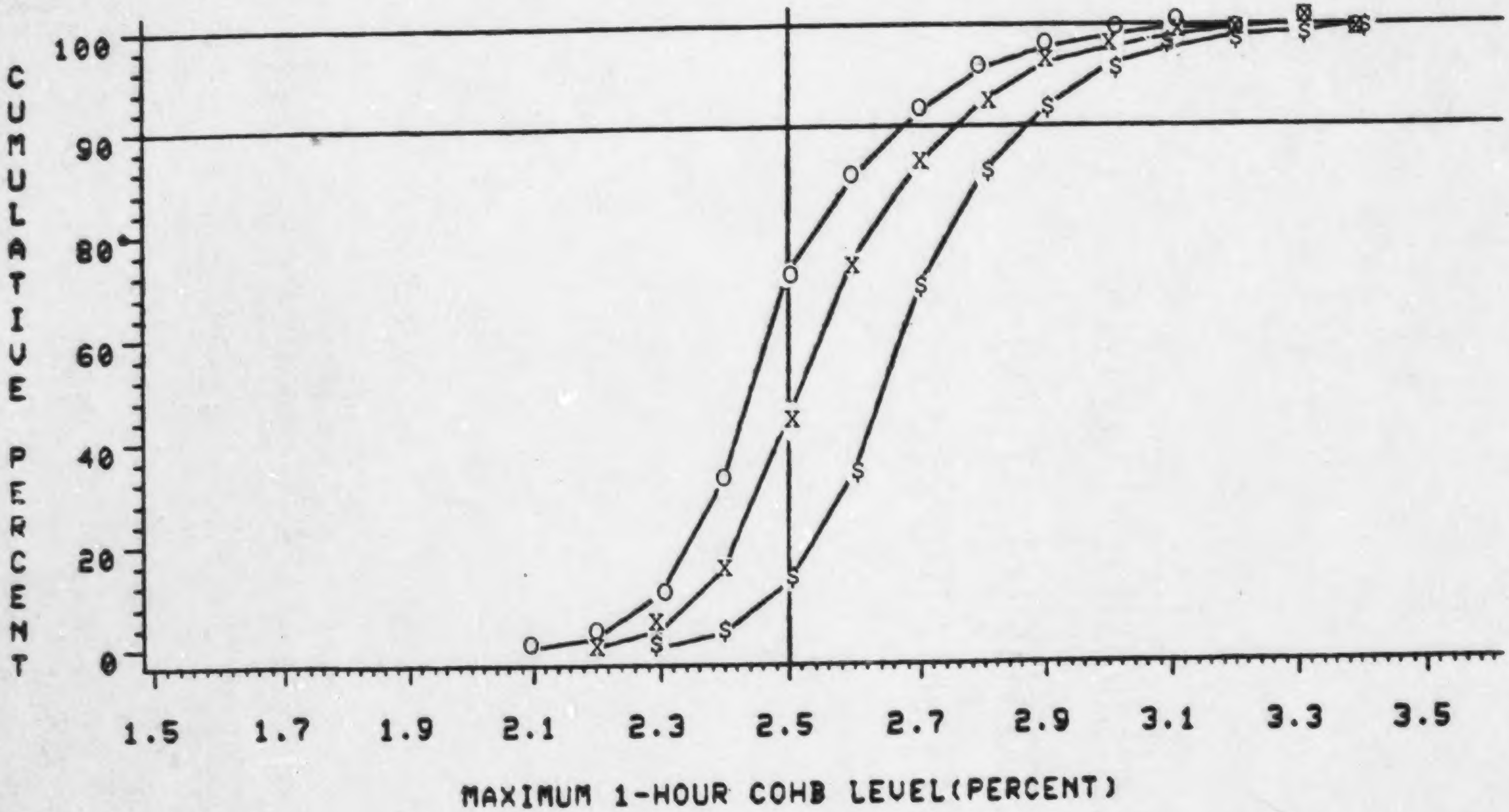
DISTRIBUTION OF M1COHB OF 400 PEOPLE
SHAPE SIMULATION MODEL
DATE=021176, VCO=.007 ML/MIN, HALDANE=230
MU5=27.56 PPM, GARAGE USE=.10, MU6=7.8 PPM, NO EXTRA COMMUTING TIME

LEGEND O-O : ALTITUDE= 0 FT.
X-X: ALTITUDE=5280 FT.

* NOTE THE CHANGE IN SCALE

FIGURE 12.2: MAXIMUM 1-HOUR BLOOD COHB LEVEL

ENDOGENOUS CO PROD. RATE COMPARISON



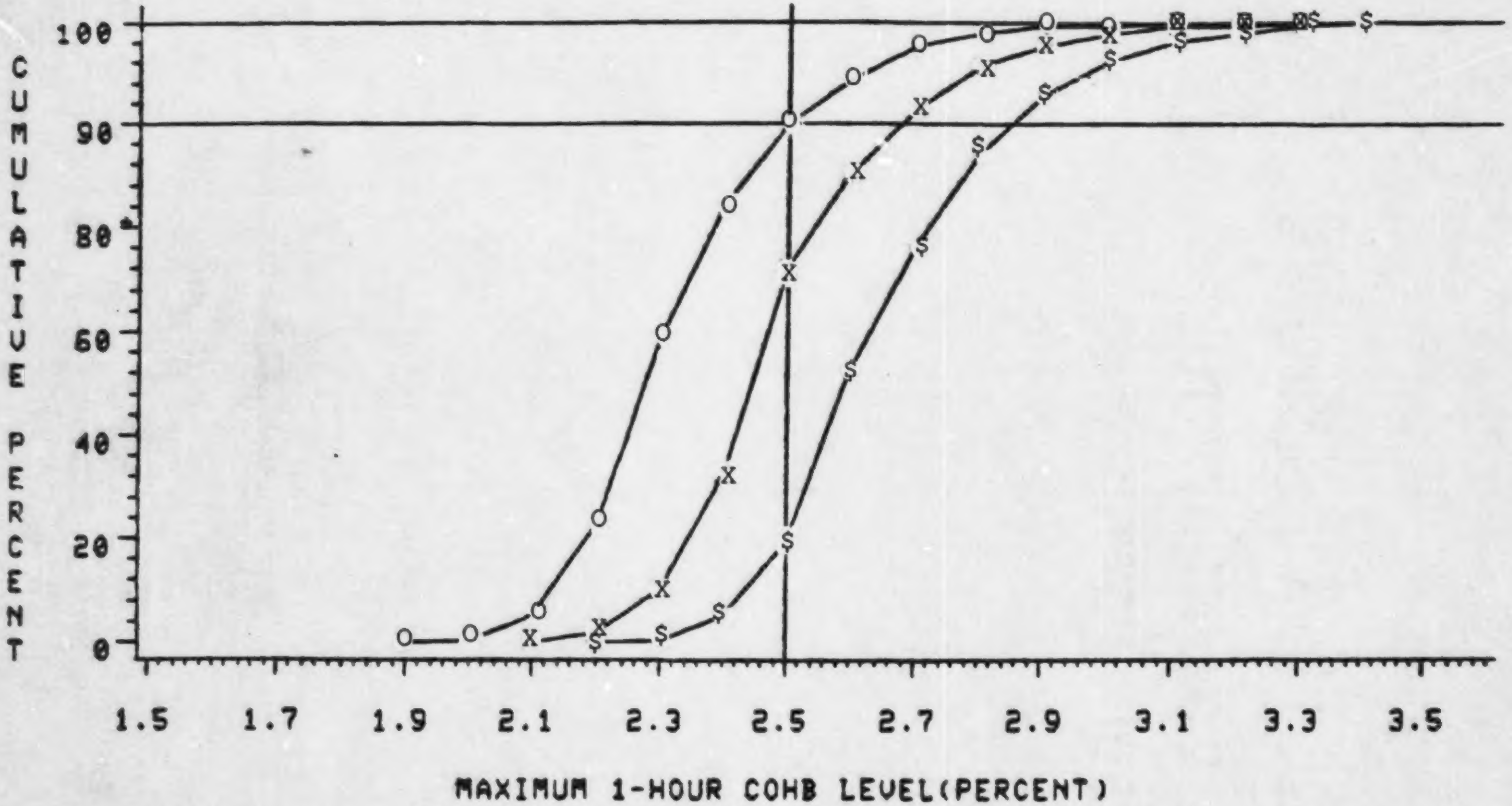
DISTRIBUTION OF M1COHB OF 400 PEOPLE
SHAPE SIMULATION MODEL
DATE=021176, ALT=0 FT., HALDANE=230
MU5=27.56 PPM, GARAGE USE=.10, MU6=7.8 PPM, NO EXTRA COMMUTING TIME (ML/MIN)

LEGEND
O-O: VCO=.007
X-X: VCO=.010
$-$: VCO=.015

* NOTE THE CHANGE IN SCALE

FIGURE 12.3: MAXIMUM 1-HOUR BLOOD COHB LEVEL

HALDANE CONSTANT COMPARISON



DISTRIBUTION OF M1COHB OF 400 PEOPLE
SHAPE SIMULATION MODEL
DATE=021176, ALT=0 FT., UCO=.007 ML/MIN
MU5=27.56 PPM, GARAGE USE=.10, MU6=7.8 PPM, NO EXTRA COMMUTING TIME

LEGEND O-O : HALDANE=210
X-X: HALDANE=230
$-$: HALDANE=250

* NOTE THE CHANGE IN SCALE

TABLE 12.3. Arithmetic Means and Standard Deviations of Maximum 1-Hour COHb Levels (Percent) of 400 People:

Altitude, Endogenous CO Production Rate and Haldane Constant

Haldane Constant	Altitude = 0 ft.			Altitude = 5280 ft.		
	Endogenous CO Production rate (ml/min)			Endogendous CO Production Rate (ml/min)		
	.007	.010	.015	.007	.010	.015
210	2.302 (.147)	2.369 (.148)	2.481 (.151)	2.457 (.147)	2.538 (.149)	2.673 (.154)
230	2.463 (.154)	2.537 (.156)	2.658 (.159)	2.630 (.154)	2.718 (.157)	2.865 (.163)
250	2.621 (.161)	2.701 (.163)	2.833 (.167)	2.798 (.161)	2.894 (.165)	3.053 (.172)

p-values: Both main effect, .0001
Interaction effects, .3365

p-values: Both main effects, .0001
Interaction effects, .1847

Date: Feb. 11, 1976
Geometric mean and standard deviation of CO concentration in parking garages: mu = 27.56 ppm,
sigma5 = 1.79

Probability of using a parking garage = .10
Geometric mean and standard deviation of CO concentration in automobiles: mu6 = 7.80 ppm,
sigma6 = 2.53

No extra commuting time

83.5%. These two points correspond to a cumulative frequency of 100% - 29.5% = 70.5% and 100% - 83.5% = 16.5% on Figure 12.1. This dramatic increase is due to a shift in the mass of the narrow M1COHb distribution, although the increase in average M1COHb, due to altitude, is a small but significant 0.167% -- from 2.463% COHb to 2.630% COHb (Table 14.2). If 3.0% COHb is considered the shift is from 0.75% to 2.25%, which is not dramatic but still significant. Because the narrowness (small variance) of the populations distribution of COHb values, the shift in the mean value is relatively small, but the shift in the number of persons in the edge of the distribution (above 2.5% or 3% COHb) can be notable.

A. Modification of Results Due to Roughton-Darling Effect

A recent paper (Collier and Goldsmith, 1983) modifies the CFK equation based on a correction for the incomplete saturation of hemoglobin by O_2 and CO. The CFK equation assumes that the hemoglobin in the pulmonary capillary is completely saturated with O_2 and CO so that COHb + O_2Hb=100%. However, complete saturation is not attained, and Roughton and Darling (1944) showed that the effect of CO on the O_2Hb dissociation curve (ODC) could be described by a total effective saturation pressure:

$$S = P_{C_{O_2}} + M \times P_{ICO},$$

where M is the Haldane parameter, P_{CO2} is capillary O_2 pressure and P_{ICO} is inspired CO pressure.

Collier and Goldsmith (1983) introduce the empirical fit to the ODC developed earlier (Severinghaus, 1979):

$$[COHb] + [O_2Hb] = [23400/(S^3 + 150) + 1]^{-1} \times 100\%$$

Thus, at sea level (760 mmHg), with $P_{C_{O_2}}$ =100 mmHg and PI_{CO}=0 mmHg

[COHb]+[O_2Hb]=97.7% not 100% as assumed by CFK. For each ppm CO, the total effective saturation pressure increases by approximately 0.164 mmHg=($230*[760-47]*10^{-6}$). Thus at sea level, for P_B=760 mmHg and $P_{C_{O_2}}$=100mmHg, the total saturation varies with CO as follows:

CO	[O_2Hb] + [COHb]
0 ppm	97.7%
9	97.8
35	98.1
100	98.6

The net effect of this Roughton-Darling (RD) correction to the CFK is to reduce the predicted COHb levels due to the lower equilibrium COHb.

The CFK equation predicts the COHb equilibrium with alveolar CO and O_2 as follows:

$$COHb=[1+P_{C_{O_2}}/M\{(1/D_L+(P_B-47)/V_A)*V_{CO}+(P_B-47)CO*10^{-6}\}]^{-1}$$

If we define $RD=([O_2Hb]+[COHb])/100\%$, then introduction of the RD correction predicts an equilibrium COHb as follows:

$$COHb=RD*[1+P_{C_{O_2}}/M\{(1/D_L+(P_B-47)/V_A)*V_{CO}+(P_B-47)CO*10^{-6}\}]^{-1}$$

To demonstrate the magnitude of the RD effect, the SHAPE program was run with and without (RD=1) at both sea level (0 feet) and Denver elevation (5280 feet). The data set chosen for the ambient CO was the same as the Feb. 11, 1976 data set, and M was set to 230 with V_{CO} = 0.007 ml/min. By choosing the same random number generator seed, the simulation was run identically for both cases of RD = 1 and RD = 1 for 100 cases. The RD effect reduces both the predicted COHb at a given altitude and the variation of COHb with altitude, as shown in the table below and Figures 12.1, 12.4.

Effect of Roughton-Darling Correction:

100 Simulations by SHAPE

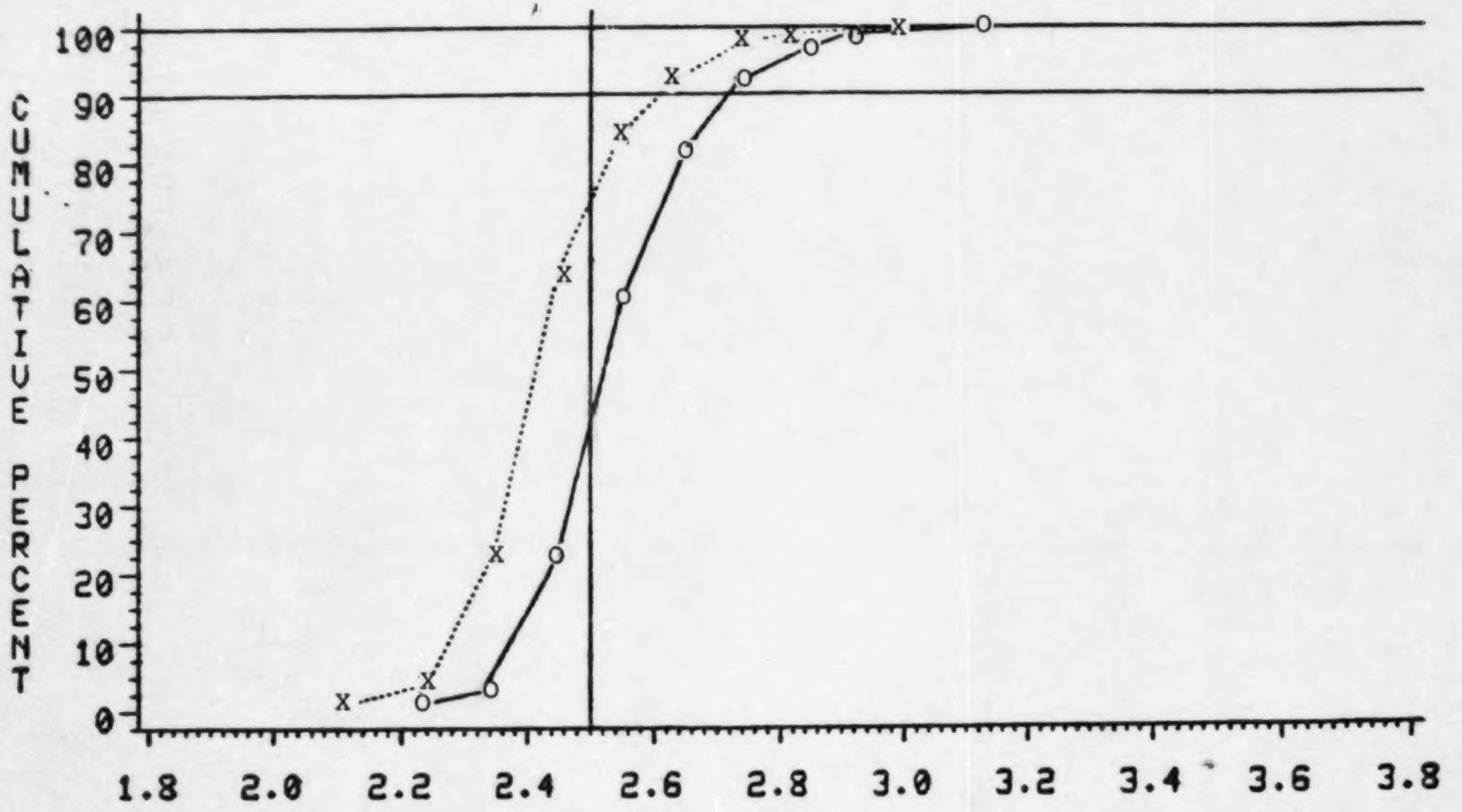
Altitude	Mean COHb%	
	RD = 1	RD ≠ 1
0 mile	2.464	2.436
1 mile	2.625	2.548

Where the CFK predicts an increase of 0.161% COHb with a 1 mile increase from mean sea level, the inclusion of the RD effect reduces the increase to 0.112% COHb. The conclusion of the previous section, that the predicted COHb increases with altitude, is unchanged. The sea level COHb distribution is shifted lower by 0.03% COHb, a negligible effect. However, the reduction of the 1 mile Denver elevation COHb distribution by 0.08% although not physiologically singificant, is statistically significant because it is of the order of one standard deviation. In this instance, by inclusion of RD $\neq$ 1, the change due to altitude of the predicted percentage of the population above 2.5% COHb is from 22% to 54% (Figure 12.4). In summary, the RD correction can be significant and should be included in all future analyses. The complexity of solving a nonlinear equation is not a consideration here, since the computer can solve the equations in a few iterations.

Please note the symbols are as shown in Appendix C.

FIGURE 12.4: MAXIMUM 1-HOUR BLOOD COHB LEVEL

ALTITUDE COMPARISON
WITH ROUGHTON DARLING CORRECTION



MAXIMUM 1-HOUR COHB LEVEL(PERCENT)
DISTRIBUTION OF M1COHB OF 100 PEOPLE
SHAPE SIMULATION MODEL
DATE=021176, VCO=.007 ML/MIN, HALDANE=230
MU5=27.56PPM, GARAGE USE=.10, MU6=7.8PPM,NO EXTRA COMMUTE

LEGEND X-X = 0 FT.
o-o =5280 FT.

VI. CONCLUSIONS

This sensitivity analysis gives a better understanding of various parameters used in SHAPE. With the enhancements to the program, the values of those physiological parameters which affect the blood COHb are sampled. Together with new formulae for calculating the values of dependent variables, the enhancements make the simulation more realistic. The comparison of the linear and nonlinear solutions to the Coburn equation confirms that for low CO exposures the linear solution is a good approximation to the nonlinear one.

Ambient CO exposure forms a major portion of total human exposure, and the three dates selected for this sensitivity analysis (Table 4) have ambient CO levels that are close to the EPA 8-hour CO standard of 9 ppm. These particular dates were chosen from a sensitivity analysis of 21 CO concentration time patterns performed earlier by EPA. Of the 21 patterns, the Los Angeles County station (Jan. 1-2, 1975) gave the lowest COHb, the Whittier station (Feb. 10-11, 1976) the highest, and the San Jose station (Nov. 23-24, 1970) a middle value. In the earlier study, ambient CO concentrations were scaled ("rolled-backed"); in the present sensitivity analysis, raw (unscaled) observations were used.

The sensitivity analysis gives a clear view of the combined effect of the parameters studied on estimates of M1COHb (Table 13). Looking at all the parameters individually, we find that the parameters associated with parking garages were insignificant and that those associated with automobiles were less critical than altitude, endogenous CO production rate, and Haldane constant (Tables 14.1 and 14.2). Altitude is known to affect blood COHb in human beings (EPA, 1978). The sensitivity analysis reaffirms this and shows the importance of the endogenous CO production rate and the Haldane constant in estimating COHb levels. Changes in these parameters shift the distributions significantly. The change in the number of people who fall above or below a certain level depends on the level chosen and the characteristics of the distribution under study. In the simulated distribution of M1COHb, the shift due to changes in these parameters causes a dramatic change in the percent of people who fall above the level of 2.5% COHb. On the other hand, the change in the average COHb is small.

The characteristics of the distributions we generated which are responsible for the dramatic change are:

- The mode of the population's 8-hour CO exposure distribution is very close to the EPA standard of 9 ppm for 8-hours.
- The mode of the 1-hour maximum blood COHb is very close to the 2.5% level chosen for analysis.

Table 13. Percentage of People with Blood MlCOHb Level of 2.5% and Above in Sample of 400 People: Feb. 11, 1976

TRAFFIC-RELATED PARAMETERS:

Probability of Parking Garage Use	Geometric Mean of CO Concentration in Parking Garages (ppm)		
	18.37	27.56	45.94
.01	34.50	34.75	35.00
.10	29.00	29.50	30.75
.20	40.50	42.00	43.50

Altitude = 0 ft
V_{CO} = 0.007 ml/min
Haldane Constant = 230
mu6 = 7.8 ppm
No extra commuting time

Extra Commuting Time (min)	Geometric Mean of CO Concentration in Automobiles (ppm)		
	3.12	7.80	13.16
0	15.75	29.50	46.00
15	25.25	56.50	75.50
30	34.75	70.75	87.00

Altitude = 0 ft
V_{CO} = 0.007 ml/min
Haldane Constant = 230
mu5 = 27.56 ppm
Probability of parking garage use = 0.10

COBURN PARAMETERS:

Altitude = 0 ft

Haldane Constant	Endogenous CO Production Rate (ml/min)		
	.007	.010	.015
210	10.00	16.50	37.75
230	29.50	54.75	87.00
250	80.50	93.00	99.50

Altitude = 5280 ft

Haldane Constant	Endogenous CO Production Rate (ml/min)		
	.007	.010	.015
210	37.75	56.25	89.50
230	83.50	95.00	100.00
250	99.00	100.00	100.00

mu5 = 27.56 ppm
mu6 = 7.8 ppm
Probability of parking garage use = 0.10
No extra commuting time

Table 14.1 Number of People With Blood M1COHb Level 2.5% and Above in a Sample of 400 People, for Various Parameter Settings (Feb. 11, 1976*).

Parameter	Values Used			Number of People With M1COHb 2.5% and Above		
Geometric (Arithmetic) Mean of CO Concentration in Parking Garages	18.37 (22)	27.56 (33)	45.94 (54)	116	118	123
Probability of Parking Garage Use	.01	.10	.20	139	118	168
Geometric (Arithmetic) Mean of CO Concentration in Automobiles (ppm)	3.12 (5)	7.80 (12)	13.6 (20)	63	118	184
Extra Commuting Time (min.)	0	15	30	118	226	283
Altitude (ft.)		0	5280		118	336
Endogenous CO Production Rate (ml/min)	0.007	0.010	0.015	118	219	348
Haldane Constant	210	230	250	40	118	322
Microenvironments	No	Yes		0	118	
*Ambient CO	11/24/70	2/11/76	1/2/75	3	118	3

Except for the parameter under consideration, all other parameter values were standard: altitude = 0 ft., V_{CO} = 0.007 ml/min, Haldane Constant = 230, mu5 = 27.56 ppm, probability of parking garage use = .10, mu6 = 7.8 ppm, no extra commuting time.

*For ambient CO comparison, 3 days' ambient CO concentrations were used.

Table 14.2 Summary of Average Blood M1COHb for a Sample of 400 People for Various Parameter Settings. (Feb 11, 1976).

Parameter	Values Used			Mean M1COHb		
Geometric (Arithmetic) Mean of CO Concentration in Parking Garages	18.37 (22)	27.56 (33)	45.94 (54)	2.458	2.463	2.475
Probability of Parking Garage Use	.01	.10	.20	2.461	2.463	2.492
Geometric (Arithmetic) Mean of CO Concentration in Automobiles (ppm)	3.12 (5)	7.80 (12)	13.6 (20)	2.405	2.463	2.535
Extra Commuting Time (min.)	0	15	30	2.463	2.537	2.618
Altitude (ft.)		0	5280		2.463	2.630
Endogenous CO Production Rate (ml/min)	0.007	0.010	0.015	2.463	2.537	2.658
Haldane Constant	210	230	250	2.302	2.463	2.621
Microenvironments	No	Yes		1.935	2.463	
*Ambient CO	11/24/70	2/11/76	1/2/75	2.221	2.463	2.261

Except for the parameter under consideration, all other parameter values were standard: altitude = 0 ft., V_{CO} = 0.007 ml/min, Haldane Constant = 230, mu5 = 27.56 ppm, probability of parking garage use = .10, mu6 = 7.8 ppm, no extra commuting time.

*For ambient CO comparison, 3 days' ambient CO concentrations were used.

- The exposure distributions are narrow (i.e., they had small variances). One reason for this narrowness is that the simulation was limited to commuters; noncommuters with low CO exposures and persons with high occupational CO exposures such as parking garage employees are not included. Also, some activities and microenvironments of importance (cooking on gas stoves and smoking) are not included in the SHAPE simulation. The computer program should be refined to include these phenomena.

Table 14.2 is included to show how an important measure of central tendency--the arithmetic mean--changes in response to the same parameter values given in Table 14.1. Comparing the two tables shows that, for small changes in the arithmetic mean, the number or percent of people above 2.5% COHb may change a great deal.

Thus, if only the mean levels are considered, we may have concluded that changes in the parameter values have a small effect. On the other hand, if the number of persons estimated to have blood levels above 2.5% COHb is considered, changes in the values of the parameters have very significant effects. These two ways of viewing COHb levels show the importance of the present analysis. However, estimates of the extreme values are likely to have the greatest error, so it is important that such analyses are compared, whenever possible, to observed data.

In conclusion, it is important to use accurate values for parameters in the computer simulation. The field studies just completed in Washington and Denver should provide information that is useful in validating and calibrating the SHAPE model.

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APPENDIX A

GEOMETRIC AND ARITHMETIC MEANS AND STANDARD DEVIATIONS OF ONE-MINUTE CO CONCENTRATION DISTRIBUTION IN 14 MICROENVIRONMENTS (Ott, 1983):[a]

Microenvironment	Geometric Mean (ppm)	Geometric Standard Deviation	Arithmetic Mean (ppm)	Arithmetic Standard Deviation
1 (Indoors: Home)	2.00	0.00	2.00	0.00
2 (Indoors: Store/Restaurant)	1.20	3.50	2.63	5.13
3 (Indoors: Work)	1.00	1.00	1.00	0.00
4 (Indoors: Recreation)	0.00	0.00	0.00	0.00
5 (Indoors: Parking Garage)	27.56	1.79	32.65	20.74
6 (In-Vehicle: Auto)	7.80[b]	2.53[b]	12.00	14.03
7 (In-Vehicle: Bus)	5.80	2.54	8.96	10.54
8 (In-Vehicle: School Bus)	5.80	2.54	8.96	10.54
9 (In-Vehicle: Truck)	8.60	1.98	10.86	8.37
10 (In-Vehicle: Rail)	0.00	0.00	0.00	0.00
11 (Center City Sidewalk)	7.00	2.00	8.90	6.99
12 (Residential Sidwalk)	0.00	0.00	0.00	0.00
13 (Park, Open Area)	0.00	0.00	0.00	0.00
14 (Bicycle)	8.60	1.98	10.86	8.37

[a] Values are the microenvironmental concentrations only (i.e., the concentration due to sources in the microenvironment, without the ambient contribution included). In some cases, it was necessary to estimate the microenvironmental component (thereby subtracting the ambient component from the field data) by using the combined judgement of the authors and their experience with field studies and field data on these microenvironments. The absolute values of these parameters are not as important in the present investigation as in other studies, since a sensitivity analysis examines the effect of changes in parameter values rather than the values themselves. Most of the changes considered in the present study cover the full range of values -- from lowest to highest -- observed for a given microenvironment.

[b] Differs slightly from value used in Ott, 1981. This difference is not expected to change results in a significant manner.

APPENDIX B

PROBABILITY DISTRIBUTIONS OF AGE, SEX, HEIGHT, HEMOGLOBIN CONTENT, COMMUTING TIME, AND COMMUTING TRAVEL MODE OF THE U.S. POPULATION

Age[a]		
years	female	male
≤ 5	.0686	.0759
6-9	.0694	.0772
10-14	.0772	.0851
15-19	.0894	.0978
20-24	.0914	.0968
25-29	.0841	.0876
30-34	.0766	.0794
35-44	.1122	.1142
45-54	.1018	.0997
55-59	.0523	.0499
60-64	.0462	.0426
65-74	.0760	.0617
75-84	.0414	.0260
≥ 85	.0314	.0059

Sex	
female	.514
male	.486

Height[a] (18-74 years)		
inches	female	male
55	.001	
56	.002	
57	.004	
58	.009	
59	.022	
60	.036	.002
61	.062	.002
62	.111	.004
63	.134	.010
64	.159	.018
65	.139	.032
66	.134	.063
67	.083	.081
68	.054	.119
69	.029	.141
70	.015	.140
71	.004	.133
72		.100
73		.074
74		.041
75		.021
76		.012

Hemoglobin Content[a] (18-74 years)		
g/100 ml	female	male
<10.0	.0051	.0009
10-10.4	.0040	.0009
10.5-10.9	.0074	.0006
11.0-11.4	.0218	.0008
11.5-11.9	.0405	.0026
12.0-12.4	.0865	.0072
12.5-12.9	.1443	.0141
13.0-13.4	.1769	.0339
13.5-13.9	.1907	.0655
14.0-14.4	.1410	.1182
14.5-14.9	.0943	.1579
15.0-15.4	.0478	.1888
15.5-15.9	.0247	.1750
16.0-16.4	.0082	.1206
16.5-16.9	.0031	.0651
17.0-17.4	.0009	.0314
17.5-17.9	.0006	.0117
≥18.0	.0003	.0048

Commuting Time[a]	
minute	prob.
≤ 4	.15
5-14	.396
15-24	.201
25-34	.141
35-44	.065
45-54	.006
55-64	.027
≥ 65	.002

Commuting[b] Travel Mode	
auto	.839
bus	.054
truck	.082
subway & train	.025

a: NHANES II, 1976-80
b: Svercl et. al. 1973

APPENDIX C

EQUATIONS, COMPUTATIONS, AND SIMULATION METHODOLOGY

C.1 Equation

The Coburn differential equation governing COHb levels is

$$\frac{d\ CO}{dt} = \dot{V}_{CO} - \frac{(COHb)_t\ P_{C_{O_2}}}{(O_2Hb)_t M \times \left\{\frac{1}{D_LCO} + \frac{P_B - P_{H_2O}}{\dot{V}_A}\right\}} + \frac{P_{I_{CO}}}{\left\{\frac{1}{D_LCO} + \frac{P_B - P_{H_2O}}{\dot{V}_A}\right\}} \qquad (1)$$

where

$d\ CO/dt$ = rate of change of carbon monoxide (CO) in the body, ml/min at STPD

M = Haldane Constant

D_LCO = lung diffusion, ml/min, torr

P_B = barometric pressure, torr

P_{H_2O} = water vapor pressure, torr

$\dot{V}_A$ = alveolar ventilation, ml/min

$\dot{V}_{CO}$ = endogenous CO production, ml/min

$P_{I_{CO}}$ = endogenous CO production, ml/min

$P_{C_{O_2}}$ = capillary O_2 pressure, torr

$(COHb)_t$ = concentration of COHb in the blood at time t, ml CO/ml blood

$(O_2Hb)_t$ = concentration of O_2Hb in the blood at time t, ml O_2/ml blood

C.2 Linear Solution Algorithm

Total body CO stores are assumed to be proportional to blood COHb and equal to the product of COHb and the blood volume (V_B). COHb changes in time and O_2Hb are assumed to be constant in the linear approximation.

$$\text{Let } R = \frac{1}{D_L CO} + \frac{P_B - P_{H_2O}}{\dot{V}_A}$$

We can substitute and integrate equation (1) to obtain

$$\frac{\dfrac{(COHb)_t \, P_{C_{O_2}}}{(O_2Hb) \times M} - \dot{V}_{CO} \times R - P_{I_{CO}}}{\dfrac{(COHb)_O P_{C_{O_2}}}{(O_2Hb) \times M} - \dot{V}_{CO} \times R - P_{I_{CO}}} = e^{-\left\{\dfrac{P_{C_{O_2}} \times t}{M \times V_B \times (O_2Hb)_T \times R}\right\}} \qquad (2)$$

where

$(COHb)_O$ = concentration of COHb at the beginning of the interval t=0.

V_B = blood volume, ml

It is customary to express COHb and O_2Hb levels as a fraction of saturation (maximum possible level). A gram of hemoglobin (Hb) can combine with 1.39 ml of CO or O_2. Therefore

COHbF = COHb x 100/(1.39 x Hb)

O_2HbF = O_2Hb x 100/(1.39 x Hb)

where Hb is measured in g%, thus to convert to g/ml it has to be divided by 100. COHbF and O_2HbF are related as

$O_2HbF = 1 - COHbF$.

Using COHbF and O_2HbF, we can rewrite equation (2) as

$$\frac{\dfrac{(COHbF)_t \times P_{C_{O_2}}}{(O_2HbF) \times M} - V_{CO} \times R - P_{I_{CO}}}{\dfrac{(COHbF)_O \times P_{C_{O_2}}}{(O_2HbF) \times M} - V_{CO} \times R - P_{I_{CO}}} = e^{-\left\{\dfrac{P_{C_{O_2}} \times t}{M \times V_B \times O_2HbF \times 0.0139 \times Hb \times R}\right\}} \quad -(3)$$

Note the right hand side of this equation requires the factor 0.0139 x Hb. If O_2Hb is assumed to be constant during the interval, we can substitute

$1 - (COHbF)_O$ for (O_2HbF). Then

$$\frac{\dfrac{(COHbF)_t \times P_{C_{O_2}}}{(1 - (COHbF)_O \times M} - \dot{V}_{CO} \times R - P_{I_{CO}}}{\dfrac{(COHbF)_O \times P_{C_{O_2}}}{(1 - (COHbF)_O \times M} - \dot{V}_{CO} \times R - P_{I_{CO}}} = e^{-\left\{\dfrac{P_{C_{O_2}} \times t}{M \times V_B \times 0.0139 \times Hb \times (1-(COHbF)_O \times R}\right\}} \quad -(4)$$

Let

$$F = e^{-\left\{\dfrac{-P_{C_{O_2}} \times t}{M \times V_B \times 0.0139 \times Hb \times (1-(COHbF)_O \times R}\right\}}$$

and rearrange (4), we have

$$(\mathrm{COHbF})_t = F \times (\mathrm{COHbF})_O + \left\{(\dot{V}_{CO} \times R + P_{I_{CO}})\ (1-F)\ (1-(\mathrm{COHbF})\ ) \times M\right\} / P_{C_{O_2}} \qquad -(5)$$

If we express CO as a concentration in parts per million (ppm), then

$$P_{I_{CO}} = (P_B - P_{H_2}) \times CO \times 10^{-6}$$

Substituting into (5), we have

$$(\mathrm{COHbF})_t = \left\{F \times (\mathrm{COHbF})_O + (V_{CO} \times R + (P_B - P_{H_2O}) \times CO \times 10^{-6}) \times (1 - F) \times (1 - (\mathrm{COHbF})_O) \times M\right\} / P_{C_{O_2}} \qquad -(6)$$

$$\text{Let } C = \left\{(V_{CO} \times R + (P_B - P_{H_2O}) \times CO \times 10^{-6}) \times M\right\} / P_{C_{O_2}}$$

then

$$(\mathrm{COHbF})_t = F \times (\mathrm{COHbF})_O + C \times (1 - F) \times (1 - (\mathrm{COHbF})_O) \qquad (7)$$

Equation (7) estimates carboxyhemoglobin (as a fraction of saturation) at the end of a time period t (in minutes) where $(\mathrm{COHbF})_O$ was the concentration at the beginning of the period and the person was exposed to an average CO ppm during the period.

SHAPE has been modified to calculate $(\mathrm{COHbF})_t$ for each person in the simulation, using equation (7) at the end of each hour (t=60) over a 24-hour period.

C.3 Nonlinear Solution Algorithm

If O_2Hb is not assumed to be constant, then equation (1) in C.1 is nonlinear in COHb as O_2Hb also varies with COHb.

Marcus (1981) gave an explicit solution which expresses time t as a function of COHb

$$kt = (\text{COHbF})_t - (\text{COHbF})_0 + (1-(\text{COHbF})\ ) - \ln \frac{\{(\text{COHbF}) - (\text{COHbF})_0\}}{\{(\text{COHbF}) - (\text{COHbF})_t\}}$$

where (COHbF) is COHb at equilibrium due to a constant CO exposure

$$\frac{(\text{COHbF})}{1 - (\text{COHbF})} = C,$$

$$k = P_{C_{O_2}} / \{M \times V_B \times 0.0139 \times Hb \times R \times (O_2\text{HbF})\}$$

where C and R are as defined in C.2.

$$(\text{COHbF}) = \frac{C}{1 + C}$$

As the CO concentration during the interval is assumed to be constant, we can use the interactive method to solve equation (8) for values of t. By successive interaction with trial values of $(\text{COHbF})_t$, t converges to our required value of 60 minutes. Efficiency of convergence in interation depends on the initial trial value and the upper and lower bounds between which the interation proceeds. Successive trial value of (COHbF) produces a series of t values: t_1, t_2, ... t_n. We establish the stopping rule for the iteration as

$$60 - \Delta t \leq t_i \leq 60 + \Delta t$$

where Δt is 0.1 minute. When this condition is satisfied $(\text{COHbF})_{t_i}$ is the required COHb estimate.

It is known that the linear solution is close to the nonlinear one at low CO levels (<50 ppm). Therefore, we use the linear solution to obtain the initial trial value and the initial upper and lower bounds z_1 and z_2.

Algorithm

Step 1: $F = \mathrm{Exp}(-60k)$

Step 2: Trial Value

$$(\mathrm{COHbF})_{t_1} = F \times (\mathrm{COHbF})_0 + C \times (1 - F) \times (1 - (\mathrm{COHbF})_0)$$

Step 3:
$$t_1 = \Bigl\{ (\mathrm{COHbF})_{t_1} - (\mathrm{COHbF})_0 + (1 - (\mathrm{COHbF})\ )\ \ln \frac{(\ (\mathrm{COHbF}) - (\mathrm{COHbF})_0}{(\ (\mathrm{COHbF}) - (\mathrm{COHbF})_{t_1}\ )} \Bigr\} /k$$

Step 4: if $60 - t \leq t_1 \leq 60 = \Delta t$, then

$(\ (\mathrm{COHbF})_t = (\mathrm{COHbF})_{t_1}$ is the solution

Step 5: if not and t_1 is $> 60 + \Delta t$

then let $z_2 = (\mathrm{COHbF})_{t_1}$, and upper bound

$F = \mathrm{Exp} - (\ (60 - (t_1 - 60) - 1) \times k)$

Repeat 2, 3, and 4 to get $(\mathrm{COHbF})t_2$ and t_2, and

let $z_1 = (\mathrm{COHbF})_{t_2}$ a lower bound

otherwise if $t_1 < 60 - \Delta t$ then

let $z_1 = (\mathrm{COHbF})_{t_1}$, a lower bound

$F = \mathrm{Exp}\ (-(60 + (60 - t_1) + 1) \times k)$

Repeat 2, 3, and 4 to find $(\mathrm{COHbF})_{t_2}$ and t_2, and let $z_2 = (\mathrm{COHbF})_{t_2}$, an upper bound.

Further steps of the iteration proceed as follows:

If $t_i > 60 + \Delta t$, then $(\mathrm{COHbF})_{t_{i+1}} = \{ (\mathrm{COHbF})_{t} + z_1\}/2$

and $z_1 = (\mathrm{COHbF})_{t_i}$

If $t_1 < 60 - \Delta t$, then $(\mathrm{COHbF})_{t_{i+1}} = \{ (\mathrm{COHbF})_{t_i} + z_2\}/2$

and $z_2 = (\mathrm{COHbF})_{t_i}$

When the stopping rule is satisfied

$(\mathrm{COHbF})_{t} = (\mathrm{COHbF})_{t_i}$ is the solution.

C.4 Computation

For sensitivity analysis runs, it is assumed that the sample consists of employed people commuting to work, the connecting trip time is 10 minutes, work duration time is 9 hours, and there is no evening shopping trip.

SHAPE calculates the hourly COHb's for each person as follows:

1. Samples an individual's sex, age, height (H), and the hemoglobin content (Hb).
2. Calculates the weight (W) based on sex, age, and height with the following equations (HANES I Survey).

Female	Age	Weight
	18-24	-56.28 + 2.965 H (in)
	25-34	-88.62 + 3.587 H
	35-44	-94.02 + 3.815 H
	45-54	-77.17 + 3.587 H
	55-64	-68.24 + 3.492 H
	65-74	-76.38 + 3.583 H

Male	Age	Weight
	18-24	-172.63 + 4.842 H
	25-34	-168.67 + 4.941 H
	35-44	-187.49 + 5.277 H
	45-54	-131.83 + 4.454 H
	55-64	-173.99 + 5.069 H
	65-74	-131.64 + 4.385 H

3. Calculates the blood volume (Marcus, 1980)

$B_V = -4670 + 46.6 \quad 2.54\ H\ (in) + 21.6\ W(lb)/2.2$

4. Calculates the barometric pressure (U.S. EPA, 1978)

$P_B = 760\ \mathrm{Exp}\ (-.0000386\ \mathrm{Alt.}\ (ft)\ )$

(Altitude = 0 or 5280 ft)

5. Calculates the capillary O_2 pressure (Lambertson et al., 1952)

$P_{C_{O_2}} = 100 - 137.4\ (.0000386\ \mathrm{Alt.})$

6. Calculates the basal diffusion rate (Mohsenifar et al., 1982)

$D_L CO(\mathrm{Basal}) = -61 - .075\ \mathrm{Age} + 1.131\ H + .975\ Hb$

7. Calculates the hourly metabolic rates. The following values were assigned to those 14 microenvironments. (ASHRAE, 1971)

Microenvironment	1 (home)	.7 for sleeping (0-6 am) 1.5 otherwise
	2 (store/restaurant)	1.3
	3 (work)	1.3
	4 (recreation)	4.0
	5 (parking garage)	2.6
	6 (automobile)	1.5
	7 (bus)	1.3
	8 (school bus)	1.3
	9 (truck)	1.5
	10 (rail)	1.3
	11 (center city sidewalk)	2.6
	12 (residential sidewalk)	2.6
	13 (park, open area)	2.6
	14 (bicycle)	4.0

Based on the minute-by-minute activity profile, the metabolic rate for each minute is obtained, and hourly metabolic rates are then calculated, by averaging the minute values.

For each hour, SHAPE will then calculate

8. The alveolar ventilation (Mage, 1983)

   $\dot{V}_A = 7.5\ (1 + (\text{metabolic rate} - .8)\ ) \times 1000$

9. The lung diffusion (Personal communication: Mage, 1983)

   $D_LCO = D_LCO\ (\text{Basal}) + 4.5\ (\text{metabolic rate} - .8)$

10. $R = 1/D_LCO + (P_B - 47)/\dot{V}_A$

11. From the activity profile, a CO exposure profile is created. Hourly average microenvironmental CO concentrations are calculated and added to the ambient CO concentrations to obtain the total hourly average CO.

12. Calculates the intermediate term

    $C = M\ \{\ (R\dot{V}_{CO} + (P_B - 47) \times 10^{-6}\ (CO))\}/P_{C_{O_2}}$

    (Values of M (210, 230, or 250) and $\dot{V}_{CO}$ (0.007, 0.010, or 0.015) are preset).

13. Calculates COHb at equilibrium

    $(COHb) = C/(1 + C)$

14. Calculates

    $k = P_{C_{O_2}}\ /\{MV_B\ (.0139\ Hb)\ (1 - (COHb)\ )R\ \}$

15. Calculates

    $F = \text{Exp}\ (-60k)$

16. Refer to C.3 for the calculation of $(COHb)_t$. Δt used for the sensitivity analysis is 0.1 minute.

C.5 Summary of Computer Simulation Methodology used in SHAPE

SHAPE is a practical, inexpensive computer model designed to simulate the exposure profile of a representative sample of a population of a city. The model was designed to consider more realistically the characteristics of urban CO concentrations by simulating the activity patterns of city dwellers and thereby exposing them to varying concentrations of CO for varying time durations in specific "microenvironments" (such as a home, automobile, office, city sidewalk, parking garage) during a typical 24 hours. The program also dynamically estimates the hourly level of carboxyhemoglobin (percent COHb) attained by the sample individuals from their exposures using the Coburn physiological model (Appendix A).

The SHAPE computer simulation approach works as follows. The size of the sample population is determined by the user. It develops an "activity pattern profile" (microenvironmental status for each sampled person as a function of time of day) by allocating each minute of the person's 24-hour period into any of 14 microenvironments (home, car, office, parking garage, etc). Both the time in which a person engages in a specific activity and the transitions from one activity to another are treated as random variables that are sampled from probability distributions derived from activity pattern studies. A majority of these are available from the activity pattern data collected by the U.S. Census for the Department of Transportation, for most of the major cities in the U.S. By knowing where the person is and approximately what he or she is doing, the program "exposes" him or her to CO concentrations appropriate for that microenvironment. Random number generators provide concentration levels roughly equivalent to those found in the actual microenvironment, based on empirical field studies. For the chosen data, the CO data from one or more fixed monitoring stations of the city is used as the urban background CO concentration for that city. These sequential microenvironmental exposures and the urban background CO concentrations are brought together to form an "exposure profile" for each person from which the hourly and 8-hourly moving average CO concentrations are calculated over the 24-hour period. The consequent COHb levels are calculated from the exposure profiles. The programs pick the maximum 1-hour average exposure (M1AE), maximum moving 8-hour average exposure (MM8AE) and maximum hourly COHb level (M1COHb) for each sample person. The program repeats the above process for all persons in the simulation, thus generating the frequency distributions of M1AE, MM8AE, and M1COHb. In the present simulation, all people whose activities and exposures are simulated are assumed to be employed, and their commute habits are based on Nationwide Personal Transportation Study data of the U.S. Census Bureau.

APPENDIX D

TABLES OF SENSITIVITY ANALYSIS RESULTS USING AMBIENT CO DATA FROM SAN JOSE (NOV. 24, 1970) AND LOS ANGELES COUNTY (JAN. 2, 1975)

TABLE D1.1: CUMULATIVE DISTRIBUTIONS OF MAXIMUM1-HOUR COHB LEVELS(M1COHB) OF 400 PEOPLE FROM SHAPE SIMULATION

PARKING GARAGE CO CONCENTRATION(MUS) (PPM) AND PARKING GARAGE USE COMPARISON

(DATE= NOV. 24, 1970)

M1COHB	USE = .01			USE = .10			USE = .20		
(PERCENT)	MUS=18.37	MUS=27.56	MUS=45.94	MUS=18.37	MUS=27.56	MUS=45.94	MUS=18.37	MUS=27.56	MUS=45.94
2.8	.	.	.	.	.	0.00	.	.	0.00
2.7	.	.	.	.	.	0.50	.	.	0.25
2.6	.	.	.	.	0.00	0.75	.	.	0.50
2.5	0.00	0.00	0.00	0.00	0.75	1.25	0.00	0.00	2.00
2.4	0.50	0.50	0.50	1.25	1.25	3.00	0.75	1.50	5.00
2.3	1.75	1.75	1.75	1.75	2.50	5.00	2.25	3.50	9.75
2.2	75.25	75.25	75.25	74.00	74.25	74.50	79.25	79.25	79.25
2.1	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00

ALTITUDE= 0 FT.
ENDOGENOUS CO PRODUCTION RATE= .007 ML/MIN
HALDANE CONSTANT= 230
GEOMETRIC MEAN AND STANDARD DEVIATION OF CO CONCENTRATION IN AUTOMOBILES: MUG=7.80 PPM, SIGMAG=2.53
NO EXTRA COMMUTING TIME

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TABLE D1.2. Arithmetic Means and Standard Deviations of Maximum 1-Hour Blood Carboxyhemoglobin Levels (Percent) of 400 People From SHAPE Simulation:

Parking Garage CO Concentration and Parking Garage Use Comparison

(Date=Nov. 24, 1970)

Parking Garage Use	Geometric Means of CO Concentration in Parking Garages (ppm)		
	18.37	27.56	45.94
.01	2.220	2.220	2.221
	(.033)	(.033)	(.034)
.10	2.219	2.221	2.228
	(.036)	(.042)	(.065)
.20	2.223	2.226	2.239
	(.035)	(.041)	(.071)

Both main effects have p-value .0001
Interaction effect has p-value .0112

Altitude = 0 ft
V_{CO} = 0.007 ml/min
Haldane Constant = 230
Geometric mean and standard deviation of CO Concentration in automobiles:
mu6 = 7.80 ppm, sigma6 = 2.53
No extra commuting time

TABLE D2.1: CUMULATIVE DISTRIBUTIONS OF MAXIMUM1-HOUR COHB LEVELS(M1COHB) OF 400 PEOPLE FROM SHAPE SIMULATION
PARKING GARAGE CO CONCENTRATION(MUS) (PPM) AND PARKING GARAGE USE COMPARISON
(DATE= JAN. 2, 1975)

M1COHB	USE = .01			USE = .10			USE = .20		
(PERCENT)	MUS=18.37	MUS=27.56	MUS=45.94	MUS=18.37	MUS=27.56	MUS=45.94	MUS=18.37	MUS=27.56	MUS=45.94
2.6	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2.5	0.75	0.75	0.75	0.75	0.75	1.00	0.25	0.25	1.00
2.4	6.25	6.25	6.25	5.25	5.25	5.25	4.50	4.50	5.25
2.3	37.75	37.75	37.75	33.75	33.75	34.25	35.50	36.25	36.50
2.2	76.25	76.25	76.25	73.75	74.25	75.00	75.25	75.75	77.00
2.1	97.75	97.75	97.75	98.50	98.50	98.50	97.25	97.25	97.25
2.0	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00

ALTITUDE= 0 FT.
ENDOGENOUS CO PRODUCTION RATE= .007 ML/MIN
HALDANE CONSTANT= 230
GEOMETRIC MEAN AND STANDARD DEVIATION OF CO CONCENTRATION IN AUTOMOBILES: MUG=7.80 PPM, SIGMAG=2.53
NO EXTRA COMMUTING TIME

TABLE D2.2. Arithmetic Means and Standard Deviations of Maximum 1-Hour COHb Levels (Percent) of 400 People from SHAPE Simulation:

Parking Garage CO Concentration and Parking Garage Use

Parking Garage Use	Geometric Mean of CO Concentration in Parking Garages (ppm)		
	18.37	27.56	45.94
.01	2.268	2.268	2.268
	(.089)	(.089)	(.089)
.10	2.261	2.261	2.263
	(.086)	(.086)	(.087)
.20	2.264	2.265	2.268
	(.086)	(.086)	(.088)

p-value: Main effects, CO concentration, 0.7942
Garage Use, 0.2389
Interaction effect, .9894

Date: Jan. 2, 1975
Altitude = 0 ft
V_{CO} = 0.007 ml/min
Haldane Constant = 230
Geometric mean and standard deviation of CO Concentration in automobiles:
mu6 = 7.80 ppm, sigma6 = 2.53
No extra commuting time

TABLE D3.1: CUMULATIVE DISTRIBUTIONS OF MAXIMUM 1-HOUR COHB LEVELS(MICOHB) OF 400 PEOPLE FROM SHAPE SIMULATION

AUTOMOBILE CO CONCENTRATION(MUG) (PPM) AND EXTRA COMMUTING TIME (MINUTES) COMPARISON

(DATE= NOV. 24, 1970)

MICOHB	EXTRA = 0			EXTRA = 15			EXTRA = 30		
(PERCENT)	MUG=3.12	MUG=7.80	MUG=13.16	MUG=3.12	MUG=7.80	MUG=13.16	MUG=3.12	MUG=7.80	MUG=13.16
3.7	.	.	.	.	.	.	.	.	0.00
3.6	.	.	.	.	.	.	.	.	0.25
3.5	.	.	.	.	.	.	.	.	0.25
3.4	.	.	.	.	.	.	.	.	0.50
3.3	.	.	.	.	.	.	.	.	0.50
3.2	.	.	.	.	.	.	.	.	0.75
3.1	.	.	0.00	.	.	.	.	.	0.75
3.0	.	.	0.25	.	.	0.00	.	.	0.75
2.9	.	.	0.50	.	.	0.25	.	0.00	2.00
2.8	.	.	1.00	.	.	0.75	.	0.25	4.00
2.7	.	.	1.50	.	.	1.50	.	0.50	8.00
2.6	.	0.00	2.25	.	.	4.25	.	1.00	12.25
2.5	.	0.75	3.50	.	0.00	8.00	0.00	2.50	18.75
2.4	0.00	1.25	6.00	0.00	0.75	14.25	0.25	4.00	33.75
2.3	0.50	2.50	9.75	0.50	5.25	29.00	1.75	13.00	55.50
2.2	64.00	74.25	83.00	67.00	87.00	94.00	72.00	94.25	97.75
2.1	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00

ALTITUDE= 0 FT.
ENDOGENOUS CO PRODUCTION RATE= .007 ML/MIN
HALDANE CONSTANT= 230
GEOMETRIC MEAN AND STANDARD DEVIATION OF CO CONCENTRATION IN PARKING GARAGES: MUS=27.56 PPM, SIGMAS=1.70
PROBABILITY OF USING PARKING GARAGE= .10

TABLE D3.2. Arithmetic Means and Standard Deviations of Maximum 1-Hour COHb Levels (Percent) of 400 People from SHAPE Simulation:

Automobile CO Concentration and Commuting Time (Date=Nov. 24, 1970)

Extra Commuting Time (Minutes)	Geometric Mean of CO Concentration in Automobiles (ppm)		
	3.12	7.80	13.16
0	2.208	2.221	2.250
	(.027)	(.042)	(.105)
15	2.212	2.237	2.298
	(.028)	(.038)	(.118)
30	2.220	2.263	2.384
	(.033)	(.071)	(.189)

p-value: Both main effects and interaction effect, .0001

Date: Nov. 24, 1970
Altitude=0 ft
V_{CO}=0.007 ml/min
Haldane Constant=230
Geometric mean and standard deviation of CO concentration in parking
garage: mu5=27.56 ppm, sigma6=1.79
Probability of using parking garage=0.10

TABLE D4.1: CUMULATIVE DISTRIBUTIONS OF MAXIMUM 1-HOUR COHB LEVELS(MICOHB) OF 400 PEOPLE FROM SHAPE SIMULATION

AUTOMOBILE CO CONCENTRATION:MU6) (PPM) AND EXTRA COMPUTING TIME (MINUTES) COMPARISON

(DATE= JAN. 2, 1975)

MICOHB	EXTRA = 0			EXTRA = 15			EXTRA = 30		
(PERCENT)	MU6=3.12	MU6=7.80	MU6=13.16	MU6=3.12	MU6=7.80	MU6=13.16	MU6=3.12	MU6=7.80	MU6=13.16
3.9	.	.	.	.	.	.	.	.	0.00
3.8	.	.	.	.	.	.	.	.	0.25
3.7	.	.	.	.	.	.	.	.	0.25
3.6	.	.	.	.	.	.	.	.	0.25
3.5	.	.	.	.	.	.	.	.	0.25
3.4	.	.	.	.	.	.	.	.	0.25
3.3	.	.	.	.	.	.	.	.	0.25
3.2	.	.	.	.	.	.	.	.	0.25
3.1	.	.	.	.	.	.	.	0.00	0.25
3.0	.	.	.	.	.	0.00	.	0.25	0.75
2.9	.	.	.	.	.	0.25	.	0.25	1.25
2.8	.	.	0.00	.	.	0.25	.	0.25	1.75
2.7	.	.	0.25	.	.	0.25	.	0.25	2.50
2.6	0.00	0.00	0.75	.	.	0.75	0.00	0.50	3.50
2.5	0.25	0.75	2.75	0.00	0.00	1.75	0.25	1.25	6.00
2.4	4.75	5.25	8.50	1.00	2.00	9.75	4.00	8.00	21.25
2.3	30.50	33.75	39.00	27.75	33.25	44.00	33.50	43.00	55.75
2.2	70.50	74.25	77.00	66.25	74.50	83.00	69.00	79.50	88.25
2.1	97.75	98.50	99.00	98.25	99.25	99.75	96.25	98.75	100.00
2.0	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	.

ALTITUDE= 0 FT.
ENDOGENOUS CO PRODUCTION RATE= .007 ML/MIN
HALDANE CONSTANT= 230
GEOMETRIC MEAN AND STANDARD DEVIATION OF CO CONCENTRATION IN PARKING GARAGES: MU5=27.56 PPM, SIGMA5=1.79
PROBABILITY OF USING PARKING GARAGE= .10

TABLE D4.2. Arithmetic Means and Standard Deviations of Maximum 1-Hour COHb Levels (Percent) of 400 People from SHAPE Simulation:

Automobile CO Concentration vs. Extra Commuting Time (Date=Jan. 2, 1975)

Extra Commuting Time (Minutes)	Geometric Mean of CO Concentration in Automobiles (ppm)		
	3.12	7.80	13.16
0	2.253 (.086)	2.261 (.086)	2.276 (.096)
15	2.244 (.079)	2.260 (.069)	2.288 (.094)
30	2.254 (.088)	2.281 (.097)	2.333 (.150)

p-value: Both main effects and interaction effect, .0001

Date: Jan. 2, 1975
V_{CO}=0.007 ml/min
Haldane Constant=230
Geometric mean and standard deviation of CO concentration in parking garage: mu5=27.56 ppm, sigma6=1.79
Probability of using parking garage=0.10
Altitude=0 ft

TABLE D5.1: CUMULATIVE DISTRIBUTIONS OF MAXIMUM 1-HOUR COHB LEVELS(MICOHB) OF 400 PEOPLE FROM SHAPE SIMULATION

ENDOGENOUS CO PRODUCTION RATE(UCO) (ML/MIN) AND HALDANE CONSTANT COMPARISON

(DATE= NOV. 24, 1970 ALTITUDE= 0 FT.)

MICOHB	HALDANE 210			HALDANE 230			HALDANE 250		
(PERCENT)	UCO=.007	UCO=.010	UCO=.015	UCO=.007	UCO=.010	UCO=.015	UCO=.007	UCO=.010	UCO=.015
3.0	.	.	.	.	.	.	.	.	0.00
2.9	.	.	.	.	.	.	.	0.00	0.75
2.8	.	.	.	.	.	0.00	0.00	0.25	1.25
2.7	.	.	.	.	0.00	0.75	0.50	0.75	2.75
2.6	.	.	0.00	0.00	0.50	1.00	1.00	1.75	50.75
2.5	.	0.00	0.75	0.75	1.00	2.25	2.00	23.50	95.00
2.4	0.00	0.50	1.00	1.25	1.75	55.25	51.50	95.75	100.00
2.3	0.75	1.00	1.75	2.50	32.50	100.00	100.00	100.00	.
2.2	1.00	1.75	58.00	74.25	100.00	.	.	.	.
2.1	3.00	45.50	100.00	100.00	.	.	.	.	.
2.0	95.75	100.00	.	.	.	.	.	.	.
1.9	100.00	.	.	.	.	.	.	.	.

GEOMETRIC MEAN AND STANDARD DEVIATION OF CO CONCENTRATION IN PARKING GARAGES: MU5=27.56 PPM, SIGMA5=1.79
PROBABILITY OF USING PARKING GARAGE= .10
GEOMETRIC MEAN AND STANDARD DEVIATION OF CO CONCENTRATION IN AUTOMOBILES: MU6=7.80 PPM, SIGMA6=2.53
NO EXTRA COMMUTING TIME

TABLE D5.2: CUMULATIVE DISTRIBUTIONS OF MAXIMUM 1-HOUR COHB LEVELS(M1COHB) OF 400 PEOPLE FROM SHAPE SIMULATION

ENDOGENOUS CO PRODUCTION RATE(UCO) (ML/MIN) AND HALDANE CONSTANT COMPARISON

(DATE= NOV. 24, 1970 ALTITUDE= 5280 FT.)

M1COHB	HALDANE 210			HALDANE 230			HALDANE 250		
(PERCENT)	UCO=.007	UCO=.010	UCO=.015	UCO=.007	UCO=.010	UCO=.015	UCO=.007	UCO=.010	UCO=.015
3.3	.	.	.	.	.	.	.	.	0.00
3.2	.	.	.	.	.	.	.	.	0.75
3.1	.	.	.	.	.	0.00	.	0.00	1.25
3.0	.	.	.	.	.	0.25	0.00	1.00	5.75
2.9	.	.	.	.	0.00	1.25	1.00	1.75	46.00
2.8	.	.	0.00	0.00	0.75	3.25	1.75	12.75	88.50
2.7	.	0.00	1.00	1.00	1.25	40.50	14.50	70.75	100.00
2.6	0.00	0.75	2.00	1.25	10.75	91.00	74.50	99.75	.
2.5	0.75	1.25	27.00	16.25	74.75	100.00	100.00	100.00	.
2.4	1.25	6.00	91.25	87.00	100.00	.	.	.	.
2.3	13.25	79.00	100.00	100.00	.	.	.	.	.
2.2	95.25	100.00	.	.	.	.	.	.	.
2.1	100.00	.	.	.	.	.	.	.	.

GEOMETRIC MEAN AND STANDARD DEVIATION OF CO CONCENTRATION IN PARKING GARAGES: MU5=27.56 PPM, SIGMA5=1.79
PROBABILITY OF USING PARKING GARAGE= .10
GEOMETRIC MEAN AND STANDARD DEVIATION OF CO CONCENTRATION IN AUTOMOBILES: MU6=7.80 PPM, SIGMA6=2.53
NO EXTRA COMMUTING TIME

TABLE D5.3. Arithmetic Means and Standard Deviations of Maximum 1-Hour COHb Levels (Percent) of 400 People From SHAPE Simulation:

Altitude and Endogenous CO Production Rate and Haldane Constant
Date: Nov. 24, 1970

Haldane Constant	Altitude = 0 ft.			Altitude = 5280 ft.		
	Endogenous CO Production rate (ml/min)			Endogendous CO Production Rate (ml/min)		
	.007	.010	.015	.007	.010	.015
210	2.037 (.039)	2.100 (.041)	2.208 (.046)	2.264 (.046)	2.340 (.050)	2.472 (.058)
230	2.221 (.042)	2.289 (.045)	2.407 (.051)	2.458 (.054)	2.541 (.059)	2.685 (.068)
250	2.400 (.048)	2.474 (.051)	2.602 (.057)	2.645 (.064)	2.737 (.068)	2.892 (.079)

p-values: Main effects, .0001
Interaction effect, .0001

p-values: Main effects, .0001
Interaction effect, .0001

Geometric mean and standard deviation of CO concentration in parking garages: mu5 = 27.56 ppm, sigma5 = 1.79
Probability of using a parking garage = .10
Geometric mean and standard deviation of CO concentration in automobiles: mu6 = 7.80 ppm, sigma6 = = 2.53
No extra commuting time

TABLE D6.1: CUMULATIVE DISTRIBUTIONS OF MAXIMUM 1-HOUR COHB LEVELS(MICOHB) OF 400 PEOPLE FROM SHAPE SIMULATION
ENDOGENOUS CO PRODUCTION RATE(UCO) (ML/MIN) AND HALDANE CONSTANT COMPARISON
(DATE= JAN. 2, 1975 ALTITUDE= 0 FT.)

MICOHB	HALDANE 210			HALDANE 230			HALDANE 250		
(PERCENT)	UCO=.007	UCO=.010	UCO=.015	UCO=.007	UCO=.010	UCO=.015	UCO=.007	UCO=.010	UCO=.015
3.1	.	.	.	.	.	.			
3.0	.	.	.	.	.	.	.	.	0.00
2.9	.	.	.	.	.	.	.	.	0.25
2.8	.	.	.	.	.	0.00	.	0.00	1.00
2.7	.	.	0.00	.	.	0.25	0.00	0.25	5.75
2.6	.	.	0.25	.	0.00	1.50	0.25	2.25	28.00
2.5	.	0.00	1.50	0.00	0.50	7.50	2.50	13.25	59.75
2.4	0.00	0.75	11.50	0.75	4.00	41.00	14.75	48.25	88.25
2.3	1.25	6.50	52.50	5.25	26.75	72.50	53.25	78.75	100.00
2.2	11.75	43.50	85.50	33.75	64.00	97.75	84.00	98.75	.
2.1	55.00	82.75	100.00	74.25	94.75	100.00	100.00	100.00	.
2.0	93.25	100.00	.	98.50	100.00	.	.	.	.
1.9	100.00	.	.	100.00	.	.	.	.	.

GEOMETRIC MEAN AND STANDARD DEVIATION OF CO CONCENTRATION IN PARKING GARAGES: MU5=27.56 PPM, SIGMA5=1.79
PROBABILITY OF USING PARKING GARAGE= .10
GEOMETRIC MEAN AND STANDARD DEVIATION OF CO CONCENTRATION IN AUTOMOBILES: MU6=7.80 PPM, SIGMA6=2.53
NO EXTRA COMMUTING TIME

TABLE D6.2: CUMULATIVE DISTRIBUTIONS OF MAXIMUM 1-HOUR COHB LEVELS(M1COHB) OF 400 PEOPLE FROM SHAPE SIMULATION

ENDOGENOUS CO PRODUCTION RATE(UCO) (ML/MIN) AND HALDANE CONSTANT COMPARISON

(DATE= JAN. 2, 1975 ALTITUDE= 5280 FT.)

M1COHB	HALDANE 210			HALDANE 230			HALDANE 250		
(PERCENT)	UCO=.007	UCO=.010	UCO=.015	UCO=.007	UCO=.010	UCO=.015	UCO=.007	UCO=.010	UCO=.015
3.4	.	.	.	.	.	.	.	.	0.00
3.3	.	.	.	.	.	.	.	.	0.25
3.2	.	.	.	.	.	.	.	.	0.50
3.1	.	.	.	.	.	0.00	.	0.00	2.50
3.0	.	.	.	.	.	0.50	0.00	0.50	9.00
2.9	.	.	0.00	.	0.00	2.75	0.25	2.50	34.00
2.8	.	.	0.50	0.00	0.75	11.75	2.50	12.50	61.25
2.7	.	0.00	2.50	0.50	4.00	42.50	10.50	41.50	83.25
2.6	0.00	1.00	14.75	3.00	21.00	70.00	39.00	70.25	98.25
2.5	1.00	5.00	47.50	21.00	54.50	93.00	70.75	93.00	100.00
2.4	5.50	30.50	79.00	56.00	83.75	100.00	93.75	100.00	.
2.3	34.50	66.00	98.75	87.25	99.25	.	100.00	.	.
2.2	73.00	95.25	100.00	100.00	100.00	.	.	.	.
2.1	98.25	100.00	.	.	.	.	.	.	.
2.0	100.00	.	.	.	.	.	.	.	.

GEOMETRIC MEAN AND STANDARD DEVIATION OF CO CONCENTRATION IN PARKING GARAGES: MU5=27.56 PPM, SIGMA5=1.79
PROBABILITY OF USING PARKING GARAGE= .10
GEOMETRIC MEAN AND STANDARD DEVIATION OF CO CONCENTRATION IN AUTOMOBILES: MU6=7.80 PPM, SIGMA6=2.53
NO EXTRA COMMUTING TIME

TABLE D6.3. Arithmetic Means and Standard Deviations of Maximum 1-Hour COHb Levels (Percent) of 400 People from SHAPE Simulation:

Altitude, Endogenous CO Production Rate, and Haldane Constant
Date: Jan. 2, 1975

Haldane Constant	Altitude = 0 ft. Endogenous CO Production rate (ml/min)			Altitude = 5280 ft. Endogendous CO Production Rate (ml/min)		
	.007	.010	.015	.007	.010	.015
210	2.111 (.076)	2.183 (.080)	2.302 (.087)	2.262 (.088)	2.349 (.094)	2.494 (.104)
230	2.261 (.086)	2.340 (.090)	2.471 (.098)	2.418 (.099)	2.512 (.105)	2.671 (.116)
250	2.406 (.096)	2.491 (.100)	2.634 (.109)	2.567 (.110)	2.670 (.117)	2.841 (.130)

p-values: Main effects,0.0001
Interaction effect,0.0027

p-values: Main effects,0.0001
Interaction effect,0.0038

Geometric mean and standard deviation of CO concentration in parking garages: mu5=27.56 ppm, sigma5=1.79
Probability of using a parking garage = .10
Geometric mean and standard deviation of CO concentration in automobiles: mu6 = 7.80 ppm, sigma6 = 2.53
No extra commuting time

TABLE D7. Percentage of People with Blood MlCOHb Level of 2.5 Percent and Above from SHAPE Simulation

(Date=Nov. 24, 1970 Sample size=400 people)

Probability of Parking Garage Use	Geometric Mean of CO Concentration in Parking Garages (ppm)		
	18.37	27.56	45.94
.01	0	0	0
.10	0	.75	1.25
.20	0	0	2.00

Altitude=0 ft
V_{CO}=0.007 ml/min
Haldane=230
mu6=7.8 ppm
No extra commuting time

Extra Commuting Time (min)	Geometric Mean of CO Concentration in Automobiles (ppm)		
	3.12	7.80	13.16
0	0	.75	3.50
15	0	0	8.00
30	0	2.50	18.75

Altitude=0 ft
V_{CO}=0.007 ml/min
Haldane=230
mu5=27.56 ppm
Probability of parking garage use=0.10

Altitude = 0 ft.

Haldane Constant	Endogenous CO Production Rate (ml/min)		
	.007	.010	.015
210	0	0	.75
230	.75	1.00	2.25
250	2.00	23.50	99.00

Altitude = 5280 ft.

Haldane Constant	Endogenous CO Production Rate (ml/min)		
	.007	.010	.015
210	.75	1.25	27.00
230	16.25	74.75	100.00
250	100.00	100.00	100.00

mu5=27.56 ppm
Probability of parking garage use=0.10
mu6=7.8 ppm
No extra commuting time

TABLE D8. Percentage of People with Blood MlCOHb Level of 2.5 Percent and Above from SHAPE Simulation

(Date=Jan. 2, 1975 Sample size=400 people)

Probability of Parking Garage Use	Geometric Mean of CO Concentration in Parking Garages (ppm)		
	18.37	27.56	45.94
.01	.75	.75	.75
.10	.75	.75	1.00
.20	.25	.25	1.00

Altitude=0 ft
V_{CO}=0.007 ml/min
Haldane Constant=230
mu6=7.8 ppm
No extra commuting time

Extra Commuting Time (min)	Geometric Mean of CO Concentration in Automobiles (ppm)		
	3.12	7.80	13.16
0	.25	.75	2.75
15	0	0	1.75
30	.25	1.25	6.00

Altitude=0 ft
V_{CO}=0.007 ml/min
Haldane Constant=230
mu5=27.56 ppm
Probability of parking garage use=.10

Altitude=0 ft.

Haldane Constant	Endogenous CO Production Rate (ml/min)		
	.007	.010	.015
210	0	0	1.50
230	.75	4.00	41.00
250	14.75	48.25	88.25

Altitude=5280 ft.

Haldane Constant	Endogenous CO Production Rate (ml/min)		
	.007	.010	.015
210	1.00	5.00	47.50
230	21.00	54.50	93.00
250	70.75	93.00	100.00

mu5=27.56 ppm
mu6=7.8 ppm
Probability of parking garage use=0.10
No extra commuting time

APPENDIX E

FORTRAN SOURCE CODE OF SHAPE

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C        SIMULATION OF HUMAN ATMOSPHERIC POLLUTION EXPOSURE(SHAPE)
C ***************************************************************
C
C FORTRAN SOURCE CODE
C THE MODEL WAS DESIGNED & ORIGINALLY PROGRAMMED BY WAYNE R. OTT
C U.S. ENVIRONMENTAL PROTECTION AGENCY, INNOVATIVE RESEARCH PROGRAM
C PROGRAMMING BEGAN JULY 5, 1979.
C PROGRAM IS DESIGNED TO SIMULATE HUMAN ACTIVITY PATTERNS
C AND CONCENTRATIONS, THEREBY ALLOWING FREQUENCY DISTRIBUTIONS OF
C HUMAN EXPOSURES AND DOSAGES TO BE CALCULATED AND PREDICTED
C THIS PROGRAM IS DESIGNED FOR CARBON MONOXIDE (CO)
C THE MODEL WAS ENHANCED AND PROGRAM UPDATED BY JACOB THOMAS
C GENERAL SOFTWARE CORPORATION, EPA CONTRACT NO. 68-01-6595
C LAST UPDATE DECEMBER 1983
C ***************************************************************
C
C  * * * HOUSEKEEPING SECTION * * *
      DIMENSION LINE(33)
      COMMON /D1/N1,N2,N3,N4,N5,N21,N22,N6,N7
      COMMON /D2/CSEX(25,2),CAGEF(25,2),CAGEM(25,2)
      COMMON /D3/CHTF(25,2),CHTM(25,2),CHBF(25,2),CHBM(25,2)
      COMMON /D4/CEMPF(25,2),CEMPM(25,2)
      DIMENSION RMET1(24),IACT(1440),RMET(1440)
      DIMENSION CO1MAX(1000),CO8MAX(1000),COHBMX(1000)
      DIMENSION CO(1440)
      DIMENSION ICO(1440)
      DIMENSION CO1(24),COA1(24),COT1(24),CO8(32),COHB(24)
      DIMENSION IDATE(20),VALUE(20,24)
      DIMENSION XI(100),JH(100),PV(100),CUM(100),HI(25)
      DIMENSION GPARMS(14,2),PARMS(14,2),CONTRL(14)
      COMMON /C1/IA
      COMMON /C2/PR(12)
      COMMON /C3/CWORKA(25,2),CMODE(25,2),CTRIP1(25,2),CTRIP2(25,2)
      COMMON /C4/DMODE(25,2),DTRIP(25,2),SMODE(25,2),STRIP(25,2)
      COMMON /C5/N8,N9,N10,N11,N12,N13,N14,N15,GPROB,SPROB
      COMMON /K1/IM,ID,IY
      COMMON /K2/MM,MA,MX,MD,MLINE(35)
      COMMON /H1/AVE,STD
      COMMON /H2/MARK1,JARK2,IBLANK,NLINE(50)
C
C
C  * * * USER INSTRUCTIONS * * *
C
C...SET INSTRUCTIONS INDIVIDUALLY FOR REMAINING PERSONS
C...IF EVENT TIMES ARE TO BE PRINTED, SET INS1 = 1; OTHERWISE 0
      INS1=0
C...IF MINUTE-BY-MINUTE ACTIVITY PROFILE IS TO BE PRINTED, SET INS2=1
      INS2=0
C...IF MINUTE-BY-MINUTE EXPOS. PROFILE IS TO BE PRINTED, SET INS3 = 1
      INS3=0
C...IF DIURNAL EXPOSURE PROFILE IS TO BE PRINTED, SET INS4 = 1
      INS4=0
C...IF EXPOSURE COMPUTATION USES C.L.T. MODIFICATION, SET INS5 = 1
      INS5=0
C
C
C  * * *  SUMMARY OF MICROENVIRONMENTS  * * *
C
C   1 - INDOORS: HOME
C   2 - INDOORS: STORE/RESTAURANT
C   3 - INDOORS: WORK
```

```
C    4 - INDOORS: RECREATION
C    5 - INDOORS: PARKING GARAGE
C    6 - IN-VEHICLE: AUTO
C    7 - IN-VEHICLE: BUS
C    8 - IN-VEHICLE: SCHOOL BUS
C    9 - IN-VEHICLE: TRUCK
C   10 - IN-VEHICLE: RAIL
C   11 - OUTDOORS: CENTER CITY SIDEWALK
C   12 - OUTDOORS: RESIDENTIAL SIDEWALK
C   13 - OUTDOORS: PARK, OPEN AREA (> 100 M. FROM STREETS)
C   14 - OUTDOORS: BICYCLE
C
C
C  * * *  SUMMARY OF EMPLOYMENT CODES  * * *
C
C    1 - EMPLOYED PERSON
C    2 - UNEMPLOYED PARTNER OF HOUSEHOLD (HOUSEWIFE/HOUSEHUSBAND)
C    3 - SCHOOL STUDENT (ELEMENTARY OR HIGH SCHOOL)
C    4 - PRESCHOOL PERSON (AGE 5 OR LESS)
C    5 - RETIRED PERSON
C    6 - HIGH-EXPOSURE WORKING PERSON (TAXICAB DRIVER, GARAGE ATTENDANT)
C
C
C  * * *  PRINT SHAPE HEADER  * * *
C
      CALL TITLE
C
C  * * *  INITIALIZATION SECTION  * * *
C
C...INITIALIZE PERSON COUNTER
      J=0
C...CLEAR DEMOGRAPHIC CODES
      ISEX=0
      A=0.0
      H=0.0
      W=0.0
      HB=0.0
      BV=0.0
      DLB=0.0
      JOB=0
C...CLEAR SUMS OF MICROENVIRONMENTAL, ABIENT, AND TOTAL EXPOSURE
      CMSUM=0.0
      CASUM=0.0
      CTSUM=0.0
C...CLEAR DATA COUNTERS
      N1=0
      N2=0
      N3=0
      N4=0
      N5=0
      N6=0
      N7=0
      N8=0
      N9=0
      N10=0
      N11=0
      N12=0
      N13=0
      N14=0
      N15=0
      N21=0
      N22=0
C...CLEAR CONCENTRATION ARRAYS
      DO 10 I=1,14
      DO 20 K=1,2
      GPARMS(I,K)=0.0
      PARMS(I,K)=0.0
   20 CONTINUE
      CONTRL(I)=1.0
   10 CONTINUE
C
C
C  * * *  DATA (INITIAL CONDITIONS) INPUT SECTION  * * *
C
C...SET N = NUMBER OF PERSONS IN THE SIMULATION
       READ (5,1001) N
C...SET M=NUMBER OF PERSONS FOR WHICH FULL PROFILES WILL BE PRINTED
       READ (5,1001) M
C...SET RANDOM NUMBER SEED
      READ(5,1001) IA
C   READ IN CONTROL VALUE TO RUN LINEAR( 1) OR NONLINEAR( 2) SOLN-COMB
      READ (5,1001) ICON
C...READ IN THE STARTING DATE
      READ(5,1001)  IDATE1
C...READ IN THE END DATE
      READ(5,1001)  IDATE2
C   READ IN ALTITUDE IN FEET
      READ (5,1002) ALT
C   READ IN HALDANE CONSTANT
      READ (5,1002) HALD
C   READ IN ENDOGENOUS CO PRODUCTION RATE PERCENT
      READ (5,1002) VCO
C   READ IN CONSTANT FOR ADJUSTING COOMUTE TIME
      READ (5,1002) ADD
C   READ IN THE PROBABILITY THAT AUTO PARKING IS IN PARKING GARAGE
      READ (5,1002) GPROB
 1001 FORMAT(2X,I8)
 1002 FORMAT (2X,F12.3)
C...READ IN THE DEMOGRAPHIC DATA
      CALL INPUT1
C...READ IN THE ACTIVITY PATTERN DATA
      CALL INPUT2
C...READ IN LN PARAMETERS FOR MICROENVIRONMENTAL CONCENTRATIONS
C...     AND SEASONAL ADJUSTMENT FACTOR FOR MICROENVIRONMENT NO. 6
      CALL INPUT3(GPARMS)
C...READ IN AMBIENT CONCENTRATION DATA
      CALL INPUT4(IDATE,VALUE)
      CALL PICK(IDATE1,IDATE2,IDATE,INDEX1,INDEX2)
C...DETERMINE DAY OF WEEK FOR THE STARTING DATE SPECIFIED BY USER
      CALL CALNDR(IDATE1,IDAY1,NREF1)
C
C
C  * * *  INITIAL CONDITIONS PRINTING SECTION  * * *
C
C
C...PRINT ALTITUDE,HALDANE CONSTANT,ENDOGENOUS CO,
C   PARKING GARAGE PROBABILITY, AND EXTRA COMMUTING TIME
      WRITE(6,250) ALT,HALD,VCO,GPROB,ADD
  250 FORMAT(1H,/,6X,'ALTITUDE: ',F5.0,5X,'HALDANE CONST: ',F5.0,5X,
     1'ENDOGENOUS CO: ',F4.3,5X,'GARAGE PROB: ',F5.3,5X,
     2'EXTRA COMMUTING TIME: ',F5.0,/)
      GO TO 2
```

```
C
C...ASSUME THAT THE COMMUTER IS AT HOME AT MIDNIGHT + 1
      IACT(1)=1
C
C...DETERMINE ACTIVITIES (DEPENDS ON PERSON TYPE)
C     IF(JOB), 510
C
C
C  * * * CONSTRUCT ACTIVITIES FOR AN URBAN COMMUTER * * *
C
      CALL COMUTR(IACT,RMET,INSTR1,ADD)
C
C
C  *   *   *   PRINT OUTPUT   *   *   *
C
C...PRINT DETAILED (MINUTE-BY-MINUTE) ACTIVITY PROFILE
      IF(INSTR2.EQ.1)   CALL MINPLO(IACT,ISEX,J,A,H,W,JOB,0)
C
C...FILL CO EXPOSURE ARRAY
      CALL EXPOS(CO,IACT,PARMS,GPARMS,INS5)
C
C...COMPUTE 1-HR AVERAGE CO CONCENTRATION
      CALL AVEHR1(CO,CO1)
C
C...COMPUTE 1-HR AVERAGE METABOLIC RATE
      CALL AVEHR1(RMET,RMET1)
C
C...STORE AMBIENT DATA FOR SELECTED DATE
C......IF MISSING VALUE IS ENCOUNTERED, USE PREVIOUS VALUE
  119 CONTINUE
  121 PREVAL=0.0
      DO 125 I=1,24
      IF (IDT.EQ.1) GO TO 122
      VAL=VALUE(INDEX2,I)
      GO TO 123
  122 VAL=VALUE(INDEX1,I)
  123 IF(VAL.EQ.99.0)   VAL=PREVAL
      COA1(I)=VAL
      PREVAL=VAL
      COT1(I)=VAL+CO1(I)
  125 CONTINUE
C
C...COMPUTE 8-HR AVERAGE CO CONCENTRATIONS
      CALL AVEHR8(COT1,CO8,17)
C...COMPUTE BLOOD COHB FROM 1-HOUR EXPOSURES
      FCOHB=COHB(24)
      CALL BLOOD(ICON,COT1,RMET1,24,FCOHB,COHB,A,H,W,
     1HB,ALT,HALD,VCO,BV,DLB,IDT,INSTR4)
C
C
C...COUNT NO. OF VALID PERSONS
C...FIND MAXIMUM HOURLY EXPOSURE AND STORE IT
      IF (IDT.EQ.1) GO TO 140
      CALL VMAX24(COT1,CTX1)
      CO1MAX(J)=CTX1
C...FIND MAXIMUM 8-HOUR EXPOSURE AND STORE IT
      CALL VMAX32(CO8,CTX2)
      CO8MAX(J)=CTX2
C...FIND MAXIMUM HOURLY COHB
      CALL VMAX24(COHB,CTX3)
      COHBMX(J)=CTX3
```

```
C...PRINT THE DEMOGRAPHIC DATA
      CALL PRINT1
C...PRINT THE ACTIVITY PATTERN DATA
      CALL PRINT2
C...PRINT PARAMETERS FOR THE MICROENVIRONMENTAL CONCENTRATIONS
    2 CONTINUE
      CALL PRINT3(PARMS,GPARMS,CONTRL)
C...PRINT METHOD USED FOR COHB ESTIMATION
      IF(ICON.EQ.1) WRITE(6,248)
      IF(ICON.EQ.2) WRITE(6,249)
  248 FORMAT(//,'COHB ESTIMATED BY LINEAR METHOD',/)
  249 FORMAT(//,'COHB ESTIMATED BY NONLINEAR METHOD',/)
C...PRINT MODIFIED PARAMETERS FOR MICROENVIRONMENT NO. 6
C     CALL SEASON(A1,A2,PARMS,GPARMS,NUM,NREF1)
C
C
C  * * *  MAIN COMPUTATION LOOP  * * *
C
    1 CONTINUE
C...TEST FOR END OF RUN
      IF(J.GE.N)   GO TO 999
C...INCREMENT PERSON COUNTER
      J=J+1
C...CLEAR ACTIVITY ARRAY, CO EXPOSURE ARR AYS
      DO 120 I=1,1440
      IACT(I)=0
      RMET(I)=0.0
      CO(I)=0.0
      ICO(I)=0
  120 CONTINUE
C...CLEAR 8-HR RUNNING AVERAGE CO ARRAY
      DO 25 I=1,32
      CO8(I)=0.0
   25 CONTINUE
C...CLEAR CO, COHB, AND METABOLIC RATE ARRAY
      DO 30 I=1,24
      CO1(I)=0.0
      COT1(I)=0.0
      COHB(I)=0.0
      RMET1(I)=0.0
   30 CONTINUE
C...FOR THE FIRST M PERSONS, PRINT FULL ACTIVITY-EXPOSURE INFORMATION
      IF(J.GT.M)   GO TO 45
C     INSTR1=1
C     INSTR2=1
C     INSTR3=1 .
      INSTR4=1
      GO TO 50
   45 INSTR1=INS1
      INSTR2=INS2
      INSTR3=INS3
      INSTR4=INS4
   50 CONTINUE
C
C  * * * SELECT RESPONDENT FROM U.S. POPULATION * * *
C
      CALL SELECT(J,ISEX,A,H,W,HB,JOB,INSTR3)
C   CALCULATE COHB BASED ON PREVIOUS DAY'S CO CONCENTRATION
      IDT=1
C
C  * * *  INITIAL ASSUMPTIONS  * * *
```

```
      WRITE(10,989)J,ICON,IDATE2,ALT,HALD,VCO,GPROB,ADD,GPARMS(5,1),
     2GPARMS(6,1),CO1MAX(J),CO8MAX(J),COHBMX(J)
  989 FORMAT(I5,I2,I7,F6.0,F5.0,2F6.3,F4.0,2F7.2,3F8.4)
C...DETERMINE SUMS OF MICROENVIRONMENTAL, AMBIENT, AND TOTAL EXPOSURES
      DO 127 I=1,24
      CMSUM=CO1(I)+CMSUM
      CASUM=COA1(I)+CASUM
      CTSUM=COT1(I)+CTSUM
  127 CONTINUE
C...PRINT DETAILED (MINUTE-BY-MINUTE) EXPOSURE PROFILE
C......IF EXPOSURES ARE TO BE PRINTED, CONVERT CONCENTRATION TO INTEGERS
      IF(INSTR3.NE.1)   GO TO 140
      DO 130 I=1,1440
      C=CO(I)+0.5
      ICO(I)=IFIX(C)
  130 CONTINUE
      CALL MINPLO(ICO,ISEX,J,A,H,W,JOB,1)
  140 CONTINUE
C...PRINT HOURLY DIURNAL EXPOSURE PROFILE
      IF (INSTR4.NE.1) GO TO 128
      CALL HRPLO(IACT,ISEX,J,A,H,W,HB,JOB,RMET1,CO1,
     1COA1,COT1,CO8,COHB,BV,DLB,IDT)
      IF (IDT.EQ.1) GO TO 128
C...PRINT MAXIMUM VALUES
      WRITE(6,201)   CTX1
  201 FORMAT(1H0,5X,'MAXIMUM HOURLY CO EXPOSURE = ',F7.4)
      WRITE(6,202)   CTX2
  202 FORMAT(1H0,5X,'MAXIMUM 8-HR RUNNING AVERAGE CO EXPOSURE = ',F7.4)
      WRITE(6,203)   CTX3
  203 FORMAT(1H0,5X,'MAXIMUM HOURLY COHB = ',F7.4)
C
C...RETURN LOOP
C
  128 CONTINUE
      IF (IDT.NE.1) GO TO 129
      IDT=2
      GO TO 119
  129 CONTINUE
      GO TO 1
  999 CONTINUE
      WRITE(6,205)   CMSUM
  205 FORMAT(1H1,5X,'MICROENVIRONMENTAL COMPONENT OF EXPOSURE = ',
     1F9.2,' PERSON-PPM-HOURS')
      WRITE(6,206)   CASUM
  206 FORMAT(1H0,5X,'AMBIENT COMPONENT OF EXPOSURE = ',11X,F9.2,
     1' PERSON-PPM-HOURS')
      WRITE(6,207)   CTSUM
  207 FORMAT(1H0,5X,'TOTAL EXPOSURE = ',25X,F10.2,' PERSON-PPM-HOURS')
      WRITE(6,210)
  210 FORMAT(1H1,1X,'RESULTS FOR DISTRIBUTION OF MAXIMUM HOURLY CO (TOTA
     1L) EXPOSURE:')
      CALL STAT(J,CO1MAX)
      WRITE(6,199)
  199 FORMAT(1H1)
      CALL HISTOG(0,J,CO1MAX,0.0,1.0,50,XI,JH,PV,CUM,HI,IH,1)
      WRITE(6,220)
  220 FORMAT(1H1,'RESULTS FOR DISTRIBUTION OF MAXIMUM 8-HOUR MOVING AVER
     1AGE EXPOSURES:')
      CALL STAT(J,CO8MAX)
      WRITE(6,199)
      CALL HISTOG(0,J,CO8MAX,0.0,0.5,50,XI,JH,PV,CUM,HI,IH,2)
      WRITE(6.230)
  230 FORMAT(1H1,'RESULTS FOR DISTRIBUTION OF MAXIMUM BLOOD CARBOXYHEMOG
     1LOBIN LEVELS:')
      CALL STAT(J,COHBMX)
      WRITE(6,199)
      CALL HISTOG(0,J,COHBMX,0.0,0.1,50,XI,JH,PV,CUM,HI,IH,3)
      WRITE(6,199)
      STOP
      END
      BLOCK DATA
      COMMON /K2/MM,MA,MX,MD,MLINE(35)
      DATA MM/'M   '/,MA/'A   '/,MX/'X   '/,MD/'.   '/
      COMMON /H2/MARK1,MARK2,IBLANK,NLINE(50)
      DATA MARK1/'*   '/,MARK2/'C   '/,IBLANK/'    '/
      END
C
C
      SUBROUTINE TITLE
C
C...SUBROUTINE TO PRINT SHAPE TITLE
C  * * *  OUTPUT PRINTING SECTION  * * *
C...PRINT SHAPE HEADER
      WRITE(6,1998)
      WRITE(6,2000)
      WRITE(6,2001)
      WRITE(6,2001)
      WRITE(6,2010)
      WRITE(6,2001)
      WRITE(6,2002)
      WRITE(6,2001)
      WRITE(6,2003)
      WRITE(6,2001)
      WRITE(6,2004)
      WRITE(6,2005)
      WRITE(6,2001)
      WRITE(6,2000)
      WRITE(6,1999)
 1998 FORMAT(1H1)
 1999 FORMAT(1H0)
 2000 FORMAT(1H ,1X,'***************************************************
     1******************************************************************
     2**************')
 2001 FORMAT(1H ,1X,'*',129X,'*')
 2010 FORMAT(1H ,1X,'*',6X,'* * *   S I M U L A T I O N   O F   H U M A
     1N   A I R   P O L L U T I O N   E X P O S U R E S  (S H A P E)
     2* * *    .    *')
 2002 FORMAT(1H ,1X,'*',60X,'V E R S I O N  1',53X,'*')
 2003 FORMAT(1H ,1X,'*',62X,'MAY 23. 1981',54X,'*')
 2004 FORMAT(1H ,1X,'*',5X,'WAYNE R. OTT',72X,
     1'U.S. ENVIRONMENTAL PROTECTION AGENCY',4X,'*')
 2005 FORMAT(1H ,1X,'*',5X,'STANFORD UNIVERSITY',65X,
     1'ORD INNOVATIVE RESEARCH PROGRAM',9X,'*')
      RETURN
      END
C
C
      SUBROUTINE INPUT1
C
C...SUBROUTINE TO READ IN DEMOGRAPHIC INPUT DATA
      COMMON /D1/N1,N2,N3,N4,N5,N21,N22,N6,N7
      COMMON /D2/CSEX(25,2),CAGEF(25,2),CAGEM(25,2)
      COMMON /D3/CHTF(25,2),CHTM(25,2),CHBF(25,2),CHBM(25,2)
      COMMON /D4/CEMPF(25,2),CEMPM(25,2)
C...READ IN SEX PROBABILITIES
      CALL ENTER(N1,CSEX)
C...READ IN CUMULATIVE AGE PROBABILITIES FOR FEMALES
      CALL ENTER(N2,CAGEF)
C...READ IN CUMULATIVE AGE PROBABILITIES FOR MALES
      CALL ENTER(N3,CAGEM)
C...READ IN CUMULATIVE HEIGHT PROBABILITIES FOR FEMALES
      CALL ENTER(N4,CHTF)
C...READ IN CUMULATIVE HEIGHT PROBABILTIES FOR MALES
      CALL ENTER(N5,CHTM)
C...READ IN CUMULATIVE HEMOGLOBIN PROBABILITIES FOR FEMALES
      CALL ENTER(N21,CHBF)
C...READ IN CUMULATIVE HEMOGLOBIN PROBABILTIES FOR MALES
      CALL ENTER(N22,CHBM)
C...READ IN EMPLOYMENT PROBABILITIES FOR FEMALES
      CALL ENTER(N6,CEMPF)
C...READ IN EMPLOYMENT PROBABILITIES FOR MALES
      CALL ENTER(N7,CEMPM)
      RETURN
      END
C
C
      SUBROUTINE INPUT2
C
C...SUBROUTINE TO READ IN ACTIVITY PATTERN DATA
      COMMON /C3/CWORKA(25,2),CMODE(25,2),CTRIP1(25,2),CTRIP2(25,2)
      COMMON /C4/DMODE(25,2),DTRIP(25,2),SMODE(25,2),STRIP(25,2)
      COMMON /C5/N8,N9,N10,N11,N12,N13,N14,N15,GPROB,SPROB
C...READ IN THE DISTRIBUTION OF TRIP ARRIVAL TIMES
      CALL ENTER(N8,CWORKA)
C...READ IN THE DISTRIBUTION OF COMMUTE MODES
      CALL ENTER(N9,CMODE)
C...READ IN THE DISTRIBUTION OF HOME-WORK TRIP TIMES, PRIVATE TRANS.
      CALL ENTER(N10,CTRIP1)
C...READ IN THE DISTRIBUTION OF HOME-WORK TRIP TIMES, PUBLIC TRANS.
      CALL ENTER(N11,CTRIP2)
C...READ IN THE DISTRIBUTION OF LUNCH TRAVEL MODES
      CALL ENTER(N12,DMODE)
C...READ IN DISTRIBUTION OF LUNCH TRIP TIMES
      CALL ENTER(N13,DTRIP)
C...READ IN PROBABILITY THAT COMMUTER TAKES EVENING TRIP
      READ(20,1011)SPROB
 1011 FORMAT (10X,F10.3)
C...READ IN DISTRIBUTION OF EVENING TRIP MODES
      CALL ENTER(N14,SMODE)
C...READ IN DISTRIBUTION OF EVENING TRIP TIMES
      CALL ENTER(N15,STRIP)
      RETURN
      END
C
C
      SUBROUTINE INPUT3(GPARMS)
C
C...SUBROUTINE TO READ IN PARAMETERS FOR THE LOGNORMAL DISTRIBUTION
C...ASSUMES THAT INPUT CONSISTS OF GEO. MEAN AND GEO. STD. DEV..
C...ONE PAIR FOR EACH MICROENVIRONMENT
      DIMENSION GPARMS(14,2)
      DO 100 I=1,14
      READ(5,1010) (GPARMS(I,J),J=1,2)
 1010 FORMAT(2F10.3)
  100 CONTINUE
      READ(5,1010) A1,A2
      RETURN
      END
C
C
      SUBROUTINE INPUT4(IDATE,VALUE)
C
C...SUBROUTINE TO READ IN AMBIENT CO DATA AND DATES
      DIMENSION IDATE(20),VALUE(20,24)
      DO 50 I=1,20
      READ(5,1020) ITEST,IDATE(I),(VALUE(I,J),J=1,24)
      IF(ITEST.EQ.99)   GO TO 60
 1020 FORMAT(I2,1X,I6,1X,24F2.0)
   50 CONTINUE
C...DO NOT COUNT "99" END CODE
   60 CONTINUE
      I=I-1
      NUM=I*24
      WRITE(6,2020)   I,NUM
 2020 FORMAT(1H0,1X,'A TOTAL OF ',I5,' RECORDS WERE READ FROM THE INPUT
     1AMBIENT DATA FILE, GIVING ',I5,' HOURLY OBSERVATIONS')
      RETURN
      END
C
C
      SUBROUTINE ENTER(N,VECTOR)
C
C...SUBROUTINE TO READ DATA INTO A UNIVARIATE CUMULATIVE
C.....PROBABILITY ARRAY
C...END EACH DATA GROUP WITH "99" IN COL 1-2
      DIMENSION VECTOR(25,2)
      N=0
      DO 10 I=1,25
      READ(20,1010) ITEST,(VECTOR(I,J),J=1,2)
 1010 FORMAT(I2,F8.1,F10.3)
      IF(ITEST.EQ.99)   GO TO 90
      N=N+1
   10 CONTINUE
   90 CONTINUE
      RETURN
      END
C
C
      SUBROUTINE PRINT1
C
C...SUBROUTINE TO PRINT DEMOGRAPHIC INPUT DATA
      COMMON /D1/N1,N2,N3,N4,N5,N21,N22,N6,N7
      COMMON /D2/CSEX(25,2),CAGEF(25,2),CAGEM(25,2)
      COMMON /D3/CHTF(25,2),CHTM(25,2),CHBF(25,2),CHBM(25,2)
      COMMON /D4/CEMPF(25,2),CEMPM(25,2)
C...CHANGE PAGE
      WRITE(6,2000)
 2000 FORMAT(1H1)
C...PRINT TITLE
      WRITE(6,2010)
 2010 FORMAT(2X,'SUMMARY OF INITIAL CONDITIONS',//)
C...PRINT SEX PROBABILITIES
      PX1=CSEX(1,2)
      PX2=CSEX(2,2)-CSEX(1,2)
      WRITE(6,2015)  PX1
 2015 FORMAT(1H ,5X,'P(FEMALE) = ',F5.3)
      WRITE(6,2020)  PX2
 2020 FORMAT(1H0,5X,'P(MALE) = ',F5.3)
C...PRINT AGE PROBABILITY DISTRIBUTION
      WRITE(6,2025)
 2025 FORMAT(1H0,//,5X,'AGE DISTRIBUTION OF WOMEN:')
      CALL PRNT(N2,CAGEF)
      WRITE(6,2035)
 2035 FORMAT(1H0,//,5X,'AGE DISTRIBUTION OF MEN:')
      CALL PRNT(N3,CAGEM)
C...PRINT HEIGHT PROBABILITY DISTRIBUTION
      WRITE(6,2040)
 2040 FORMAT(1H0,//,5X,'HEIGHT DISTRIBUTION OF WOMEN:')
      CALL PRNT(N4,CHTF)
      WRITE(6,2045)
 2045 FORMAT(1H0,//,5X,'HEIGHT DISTRIBUTION OF MEN:')
      CALL PRNT(N5,CHTM)
C...PRINT HEMOGLOBIN PROBABILITY DISTRIBUTION
      WRITE(6,2041)
 2041 FORMAT(1H0,//,5X,'HEMOGLOBIN DISTRIBUTION OF WOMEN:')
      CALL PRNT(N21,CHBF)
      WRITE(6,2042)
 2042 FORMAT(1H0,//,5X,'HEMOGLOBIN DISTRIBUTION OF MEN:')
      CALL PRNT(N22,CHBM)
C...PRINT EMPLOYMENT PROBABILITY CODES
      WRITE(6,2050)
 2050 FORMAT(1H0,//,5X,'EMPLOYMENT CODES FOR WOMEN:')
      CALL PRNTI(N6,CEMPF)
      WRITE(6,2060)
 2060 FORMAT(1H0,//,5X,'EMPLOYMENT CODES FOR MEN:')
      CALL PRNTI(N7,CEMPM)
      RETURN
      END
C
C
      SUBROUTINE PRINT2
C
C...SUBROUTINE TO PRINT ACTIVITY PATTERN INPUT DATA
      COMMON /C3/CWORKA(25,2),CMODE(25,2),CTRIP1(25,2),CTRIP2(25,2)
      COMMON /C4/DMODE(25,2),DTRIP(25,2),SMODE(25,2),STRIP(25,2)
      COMMON /C5/N8,N9,N10,N11,N12,N13,N14,N15,GPROB,SPROB
C...PRINT THE DISTRIBUTION OF TRIP ARRIVAL TIMES
      WRITE(6,2065)
 2065 FORMAT(1H0,//,5X,'DISTRIBUTION OF TRIP ARRIVAL TIMES:')
      CALL PRNT(N8,CWORKA)
C...PRINT DISTRIBUTION OF COMMUTER TRAVEL MODES
      WRITE(6,2080)
 2080 FORMAT(1H0,//,5X,'DISTRIBUTION OF HOME-WORK TRAVEL MODES:')
      CALL PRNTI(N9,CMODE)
C...PRINT HOME-WORK TRIP TIME DISTRIBUTIONS
      WRITE(6,2075)
 2075 FORMAT(1H0,//,5X,'DISTRIBUTION OF HOME-WORK TRIP TIMES (MINUTES) F
     1OR PRIVATE VEHICLES (AUTOS. + TRUCKS):')
      CALL PRNT(N10,CTRIP1)
      WRITE(6,2085)
 2085 FORMAT(1H0,//,5X,'DISTRIBUTION OF HOME-WORK TRIP TIMES (MINUTES) F
     1OR PUBLIC MODES (BUS, STREET CAR, SUBWAY, TRAIN, TAXI):')
      CALL PRNT(N11,CTRIP2)
C...PRINT PROBABILITY THAT AUTO. PARKING OCCURS IN AN INDOOR GARAGE
      WRITE(6,2090)   GPROB
      WRITE(6,2095)
 2095 FORMAT(1H0,//,5X,'DISTRIBUTION OF LUNCH TRAVEL MODES:')
      CALL PRNTI(N12,DMODE)
      WRITE(6,2100)
 2100 FORMAT(1H0,//,5X,'DISTRIBUTION OF LUNCH TRAVEL TIMES')
      CALL PRNT(N13,DTRIP)
      WRITE(6,2105)
 2105 FORMAT(1H0,//,5X,'DISTRIBUTION OF LUNCH TRIP TIMES:')
      CALL PRNTI(N13,DTRIP)
      WRITE(6,2110)   SPROB
 2110 FORMAT(1H0,//,5X,'PROBABILITY THAT COMMUTER MAKES AN EVENING SHOPP
     1ING TRIP = ',F5.3)
      WRITE(6,2115)
 2115 FORMAT(1H0,5X,'DISTRIBUTION OF EVENING SHOPPING TRIP MODES:')
      CALL PRNT(N14,SMODE)
      WRITE(6,2120)
 2120 FORMAT(1H0,5X,'DISTRIBUTION OF EVENING SHOPPING TRIP TIMES:')
      CALL PRNT(N15,STRIP)
 2090 FORMAT(1H0,5X,'PROBABILITY THAT AN AUTO COMMUTER PARKS IN AN INDOO
     1R GARAGE = ',F5.3)
C...CHANGE PAGE
      WRITE(6,2000)
 2000 FORMAT(1H1)
      RETURN
      END
C
C
      SUBROUTINE PRINT3(PARMS,GPARMS,CONTRL)
C
C...SUBROUTINE TO PRINT OUT PARAMETERS OF LOGNORMAL DISTRIBUTION
C...ALSO CONVERTS GEOMETRIC INPUT VALUES INTO VALUES FOR NORMAL DISTRI-
C...BUTION WHICH REPRESENTS THE LOGARITHM OF CONCENTRATION
      DIMENSION PARMS(14,2),GPARMS(14,2),CONTRL(14)
      WRITE(6,2001)
      WRITE(6,2005)
      WRITE(6,2010)
      WRITE(6,2015)
      WRITE(6,2020)
      DO 100 I=1,14
      GU1=GPARMS(I,1)
C...CALCULATE CONTROLLED VARIABLES
      GU2=GU1*CONTRL(I)
      GPARMS(I,1)=GU2
      IF(GU2.EQ.0.0)   GO TO 40
      GSIG=GPARMS(I,2)
      U=ALOG(GU2)
      IF(GSIG.EQ.0.0)   GO TO 50
      SIG=ALOG(GSIG)
      VAR=SIG*SIG
      AVE=EXP(U+0.5*VAR)
      STD=AVE*SQRT(EXP(VAR)-1.0)
      GO TO 60
C...SPECIAL CASE FOR GU2 EQUAL TO ZERO (ZERO MEAN AND VARIANCE)
   40 CONTINUE
      U=0.0
      AVE=0.0
      SIG=0.0
      STD=0.0
      GSIG=0.0
      GO TO 60
C...SPECIAL CASE FOR GSIG EQUAL TO ZERO (ZERO VARIANCE)
```

```
   50 CONTINUE
      VAR=0.0
      AVE=GU2
      STD=0.0
      SIG=0.0
   60 CONTINUE
      WRITE(6.2030) I,GU1,GSIG.CONTRL(I),GU2,AVE,STD,U,SIG
C...STORE COMPUTED NORMAL PARAMETERS IN ARRAY
      PARMS(I,1)=U
      PARMS(I,2)=SIG
  100 CONTINUE
 2001 FORMAT(1H ,43X,'*  *  *   ASSUMED CONCENTRATION PARAMETERS   *  *
     1 *',//)
 2005 FORMAT(1H ,36X,'INPUT VALUES',43X,'CALCULATED VALUES')
 2010 FORMAT(1H ,20X,'---------------------------------------------',
     107X,'--------------------------------------------------------'
     2)
 2015 FORMAT(1H ,72X,'CONTROLLED',4X,'ARITHMETIC PARAMETERS',5X,'NORMAL
     1DIST. OF LOGS')
 2020 FORMAT(1H ,1X,'MICROENVIRONMENT',4X,'GEO. MEAN',3X,
     1'GEO. STD. DEV.',3X,'CONTROL FACTOR',9X,'GEO. MEAN',6X,
     2'MEAN',4X,'STD. DEV.',9X,'MEAN',3X,'STD. DEV.')
 2030 FORMAT(1H0,8X,I2,11X,F7.4,6X,F7.4,11X,F7.4,14X,F7.4,6X,F7.4,
     13X,F7.4,9X,F7.4,3X,F7.4)
      RETURN
      END
C
C
      SUBROUTINE PRNT(N,VECTOR)
C
C...SUBROUTINE TO PRINT A UNIVARIATE CUMULATIVE PROBABILITY ARRAY
      DIMENSION VECTOR(25,2)
      WRITE(6,2030)
 2030 FORMAT(1H0,3X,'I',9X,'RANGE',6X,'PROBABILITY',2X,'CUM. PROB.')
      Y1=0.0
      X1=0.0
      DO 10 I=1,N
      X2=VECTOR(I,1)
      Y2=VECTOR(I,2)
      PROB=Y2-Y1
      WRITE(6,2010)  I,X1,X2,PROB,Y2
      X1=X2
      Y1=Y2
   10 CONTINUE
 2010 FORMAT(3X,I2,5X,F5.0,'-',F5.0,5X,F8.5,4X,F7.4)
      RETURN
      END
C
C
      SUBROUTINE PRNTI(N,VECTOR)
C
C...SUBROUTINE TO PRINT A UNIVARIATE CUMULATIVE PROBABILITY ARRAY
C THAT CONTAINS INTEGER CODES
      DIMENSION VECTOR(25,2)
      WRITE(6,2055)
 2055 FORMAT(1H0,/,14X,'CODE',10X,'PROB.',4X,'CUM. PROB.')
      Y1=0.0
      DO 10 I=1,N
      X2=VECTOR(I,1)
      I2=IFIX(X2)
      Y2=VECTOR(I,2)
      PROB=Y2-Y1
      WRITE(6,2010)  I,I2,PROB,Y2
 2010 FORMAT(3X,I2,10X,I2,8X,F8.5,4X,F7.4)
      X1=X2
      Y1=Y2
   10 CONTINUE
      RETURN
      END
C
C
      SUBROUTINE MINPLO(IACT,ISEX,J,A,H,W,JOB,INSTR3)
C
C...SUBROUTINE TO GIVE MINUTE-BY-MINUTE PLOT OF 24-HR EXPOSURE PROFILE
      DIMENSION IACT(1440)
      WRITE(6,2100)
      IF(ISEX.EQ.1)  WRITE(6,2102) J,A,H,W,JOB
      IF(ISEX.EQ.2)  WRITE(6,2103) J,A,H,W,JOB
      IF(INSTR3.NE.1)   WRITE(6,2104)
      IF(INSTR3.EQ.1)   WRITE(6,2105)
      WRITE(6,2106)
      DO 10 I=1,60
      I1=I
      I2=I+60
      I3=I+120
      I4=I+180
      I5=I+240
      I6=I+300
      I7=I+360
      I8=I+420
      I9=I+480
      I10=I+540
      I11=I+600
      I12=I+660
      I13=I+720
      I14=I+780
      I15=I+840
      I16=I+900
      I17=I+960
      I18=I+1020
      I19=I+1080
      I20=I+1140
      I21=I+1200
      I22=I+1260
      I23=I+1320
      I24=I+1380
      WRITE(6,2120)   I,IACT(I1),IACT(I2),IACT(I3),IACT(I4),IACT(I5),
     1IACT(I6),IACT(I7),IACT(I8),IACT(I9),IACT(I10),IACT(I11),IACT(I12),
     2IACT(I13),IACT(I14),IACT(I15),IACT(I16),IACT(I17),IACT(I18),
     3IACT(I19),IACT(I20),IACT(I21),IACT(I22),IACT(I23),IACT(I24)
   10 CONTINUE
      WRITE(6,2125)
      IF(INSTR3.NE.1)   WRITE(6,2130)
      IF(INSTR3.NE.1)   WRITE(6,2131)
      IF(INSTR3.NE.1)   WRITE(6,2132)
 2100 FORMAT(1H1)
 2102 FORMAT(/,1X,'PERSON NO.',I6,7X,'SEX: FEMALE',7X,'AGE:',F5.0,7X,
     1'HEIGHT:',F5.0,7X,'WEIGHT:',F5.0,7X,'OCCUPATIONAL CATEGORY:',I3)
 2103 FORMAT(/,1X,'PERSON NO.',I6,7X,'SEX: MALE',7X,'AGE:',F5.0,7X,
     1'HEIGHT:',F5.0,7X,'WEIGHT:',F5.0,7X,'OCCUPATIONAL CATEGORY:',I3)
 2104 FORMAT(1H0,//, 01X,'-----------------------------------
     1--ACTIVITY PROFILE---------------------------------------')
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 2105 FORMAT(1HO.//, 01X,'-----------------------------------------------
     1--EXPOSURE PROFILE------------------------------------------')
 2106 FORMAT(1H ,1X,'MIN/HR',1X,'12',3X,'1',3X,'2',3X,'3',3X,'4',3X,
     1'5',3X,'6',3X,'7',3X,'8',3X,'9',2X,'10',2X,'11',2X,'12',3X,
     2'1',3X,'2',3X,'3',3X,'4',3X,'5',3X,'6',3X,'7',3X,'8',3X,'9',
     32X,'10',2X,'11')
 2120 FORMAT(1H ,2X,I2,2X,24(1X,I3))
 2125 FORMAT(1H ,01X,'---------------------------------------------------
     1------------------------------------------------------')
 2130 FORMAT(1H ,01X,'CODES -- INDOORS:      1-HOME, 2-STORE/RESTAURANT,3
     1-WORK, 4-RECREATION, 5-PARKING GARAGE')
 2131 FORMAT(1H ,10X,'IN VEHICLE:  6-AUTO,7-BUS, 8-SCHOOL BUS, 9-TRUCK,
     110-RAIL')
 2132 FORMAT(1H ,10X,'OUTDOORS:     11-CENTER CITY, 12-RESIDENTIAL, 13-PA
     1RK, 14-BICYCLE')
      RETURN
      END
C
C
      SUBROUTINE HRPLO(IACT,ISEX,J,A,H,W,HB,JOB,RMET1,CO1,COA1,COT1,
     1CO8,COHB,BV,DLB,IDT)
C
C...SUBROUTINE TO SHOW 24-HOUR EXPOSURE PROFILE
      COMMON /K2/MM,MA,MX,MD,MLINE(35)
      COMMON /H2/MARK1,MARK2,IBLANK,NLINE(50)
      DIMENSION CO1(24),COA1(24),COT1(24),CO8(32),COHB(24)
      DIMENSION RMET1(24),IACT(1440)
      WRITE(6,2100)
      IF (IDT.NE.1) GO TO 14
      IF(ISEX.EQ.1) WRITE(6,2101) J,A,H,W,HB,BV,DLB,JOB
      IF(ISEX.EQ.2) WRITE(6,2102) J,A,H,W,HB,BV,DLB,JOB
      WRITE (6,2103)
 2103 FORMAT(/,'DIURNAL EXPOSURE PROFILE USING PREVIOUS DAY AMBIENT CO')
  14  WRITE(6,2104)
      WRITE(6,2105)
      WRITE(6,2110)
      WRITE(6,2115)
C...PRINT FIRST 12 HOURS OF EXPOSURE
      DO 20 IH=1,12
C...CLEAR ALPHABETIC ARRAYS
      DO 10 I=1,30
      MLINE(I)=IBLANK
   10 CONTINUE
      DO 15 I=1,25
      NLINE(I)=IBLANK
   15 CONTINUE .
      DO 22 MIN=1,60
      INDEX=MIN+(IH-1)*60
      LCODE=IACT(INDEX)
      IF(LCODE.NE.0)   LOC=2*LCODE
      IF(LCODE.NE.0)   MLINE(LOC)=MX
   22 CONTINUE
      LOC2=IFIX(COT1(IH)+0.5)
C     MET2=IFIX(RMET1(IH)+0.5)
      IF(LOC2.NE.0) NLINE(LOC2)=MD
      KH=IH-1
      IF(KH.EQ.0)   KH=12
      WRITE(6,2120) KH,(MLINE(J1),J1=1,30),RMET1(IH),(NLINE(K),K=1,25),
     1CO1(IH),COA1(IH),COT1(IH),CO8(IH),COHB(IH)
   20 CONTINUE
C...PRINT SECOND 12 HOURS OF EXPOSURE
```

```
      DO 25 IH=13,24
C...CLEAR ALPHABETIC ARRAYS
      DO 23 I=1,30
      MLINE(I)=IBLANK
   23 CONTINUE
      DO 24 I=1,25
      NLINE(I)=IBLANK
   24 CONTINUE
      DO 27 MIN=1,60
      INDEX=MIN+(IH-1)*60
      LCODE=IACT(INDEX)
      IF(LCODE.NE.0)   LOC=2*LCODE
      IF(LCODE.NE.0)   MLINE(LOC)=MX
   27 CONTINUE
      LOC2=IFIX(COT1(IH)+0.5)
C     MET2=IFIX(RMET1(IH)+0.5)
      IF(LOC2.NE.0) NLINE(LOC2)=MD
      KH=IH-13
      IF(KH.EQ.0)   KH=12
      WRITE(6,2122) KH,(MLINE(J1),J1=1,30),RMET1(IH),(NLINE(K),K=1,25),
     1CO1(IH),COA1(IH),COT1(IH),CO8(IH),COHB(IH)
   25 CONTINUE
      WRITE(6,2125)
C...PRINT LEGEND
      WRITE(6,2202)
      WRITE(6,2205)
      WRITE(6,2210)
      WRITE(6,2215)
      WRITE(6,2217)
 2100 FORMAT(1H1)
 2101 FORMAT(/,1X,'PERSON NO.',I6,7X,'SEX: FEMALE',7X,'AGE:',F5.0,7X,
     1'HEIGHT:',F5.0,7X,'WEIGHT:',F5.0,7X,'HEMOGLOBIN CONTENT: ',F5.2,
     2/,T25,'BLOOD VOLUME: ',F5.0,T59,'BASAL DIFFUSIVITY: ',F5.2,T97,
     3'OCCUPATIONAL CATEGORY:',I3)
 2102 FORMAT(/,1X,'PERSON NO.',I6,7X,'SEX:  MALE',7X,'AGE: ',F5.0,7X,
     1'HEIGHT:',F5.0,7X,'WEIGHT:',F5.0,7X,'HEMOGLOBIN CONTENT: ',F5.2,
     2/,T25,'BLOOD VOLUME: ',F5.0,T59,'BASAL DIFFUSIVITY: ',F5.2,T97,
     3'OCCUPATIONAL CATEGORY:',I3)
 2104 FORMAT(//,10X,'+--------------------------------------------------
     1DIURNAL EXPOSURE PROFILE------------------------------------------
     2-----+')
 2105 FORMAT(1H ,9X,'*---------MICROENVIRONMENT----------*-----*------CO
     1 CONCENTRATION------*  MICRO  * AMBIENT *  TOTAL  *  TOTAL  *  TOT
     2AL   *')
 2110 FORMAT(1H ,2X,'TIME',3X,'*  INDOORS  * IN-VEHICLE * OUTDOORS * MET
     1 * 0    5    10   15   20   25 * 1-HR CO * 1-HR CO * 1-HR CO * 8-HR
     2 CO *   COHB   *')
 2115 FORMAT(1H ,2X,'----',3X,'* H S W R G * C B S T R  * C R P B  * -
     1 * +----+----+----+----+----+ *  (PPM)  *  (PPM)  *  (PPM)  *  (PP
     2M)  *  (PCT)   *')
 2120 FORMAT(1H ,1X,I2,':00',1X,'A',1X,'I',10A1,' I',11A1,' I ',
     109A1,'I',1X,F3.1,1X,'I',1X,'I',25A1,1X,'I',
     2F6.2,3X,'I',F6.2,3X,'I',F6.2,3X,'I',F7.3,2X,'I',F7.3,3X,'*')
 2122 FORMAT(1H ,1X,I2,':00',1X,'P',1X,'I',10A1,' I',11A1,' I ',
     109A1,'I',1X,F3.1,1X,'I',1X,'I',25A1,1X,'I',
     2F6.2,3X,'I',F6.2,3X,'I',F6.2,3X,'I',F7.3,2X,'I',F7.3,3X,'*')
 2125 FORMAT(1H ,9X,'+--------------------------------------------------
     1------------------------------------------------------------------
     2-----+')
 2202 FORMAT(1H ,1X,'MICROENVIRONMENTS:')
 2205 FORMAT(1H ,5X,'INDOORS:',4X,'H-HOME; S-STORE/RESTAURANT; W-WORK;',
     11X,'G-PARKING GARAGF;',1X,'R-RECREATION')
 2210 FORMAT(1H ,5X,'IN-VEHICLE: C-CAR; B-BUS; S-SCHOOL BUS;',
     1'T-TRUCK; R-RAIL')
 2215 FORMAT(1H ,5X,'OUTDOORS:',3X,'C-CENTER CITY SIDEWALK; R-RESIDENTIA
     1L SIDEWALK; P-PARK; B-BICYCLE')
C2217 FORMAT(1H ,/,5X,'ACT = ACTIVITY LEVEL: 0-SEDENTARY;',
C    1'1-LIGHT PHYSICAL; 2-MODERATE PHYSICAL; 3-HEAVY')
 2217 FORMAT(1H,/,5X,'MET = METABOLIC RATE:   SLEEP 0.7  SEDENTARY 1.3
     1  HOUSE WORK 1.4-3.6  OFFICE WORK 1.1-1.4',/,T28,'  MODERATE ',
     2'EXERCISE 2.0-4.6   HEAVY WORK 5.0-8.7',//)
      RETURN
      END
C
C
      SUBROUTINE PICK(IDATE1,IDATE2,IDATE,INDEX1,INDEX2)
C
C...SUBROUTINE TO MATCH START/END DATES WITH THOSE OF AMBIENT DATA FILE
      DIMENSION IDATE(20)
C...CONVERT NO. OF HOURS TO NO. OF DAYS
      DO 10 I=1,20
      IF(IDATE(I).EQ.IDATE1)   INDEX1=I
      IF(IDATE(I).EQ.IDATE2)   INDEX2=I
   10 CONTINUE
      WRITE(6,2010)   IDATE1,INDEX1
      WRITE(6,2020)   IDATE2,INDEX2
 2010 FORMAT(1H0,5X,'STARTING DATE SPECIFIED BY USER, ',I6,', CORRESPOND
     1S TO RECORD NO. ',I4,' OF THE AMBIENT INPUT DATA FILE.')
 2020 FORMAT(1H0,5X,'ENDING DATE SPECIFIED BY USER, ',I6,', CORRESPONDS
     1TO RECORD NO.',I4,' OF THE AMBIENT INPUT DATA FILE.')
      RETURN
      END
C
C
      SUBROUTINE CALNDR(IDATE1,IDAY,NREF)
C
      COMMON /K1/IM,ID,IY
C...SUBROUTINE TO FIND DAY OF WEEK FOR ANY CALENDER DATE
C...ALGORITHM BASED ON HEWLETT-PACKARD HP-25 APPLICATIONS PROGRAMS, P. 4
C...0-SUNDAY, 1-MONDAY, 2-TUESDAY, 3-WED., 4-THURSDAY, 5-FRIDAY, 6-SAT.
C......FIND MONTH FROM 6-DIGIT DATE CODE
      I1=IDATE1/100
      IM=I1/100
C......FIND YEAR FROM 6-DIGIT DATE CODE
      I2=I1*100
      IY=IDATE1-I2
      IY=IY+1900
C......FIND DAY FROM 6-DIGIT DATE CODE
      I2=IM*100
      ID=I1-I2
      WRITE(6,200)
      WRITE(6,201) IM,ID,IY
C......COMPUTE NREF, THE NO. OF DAYS ELAPSED SINCE MARCH 1, 1700
      IF(IM.EQ.1.OR.IM.EQ.2)   IG=IY-1
      IF(IM.GT.2)   IG=IY
      G=FLOAT(IG)
      IF(IM.EQ.1.OR.IM.EQ.2)   JF=IM+13
      IF(IM.GT.2)   JF=IM+1
      F=FLOAT(JF)
      NREF=IFIX(365.25*G)+IFIX(30.6*F)+ID-621049
      NDAY=MOD(NREF,7)
      WRITE(6,210) NDAY
```

```
  200 FORMAT(1H0,1X,'COMPUTATION OF DAY OF WEEK FOR SPECIFIED DATE:')
  201 FORMAT(1H0,1X,'MONTH = ',I2,5X,'DAY = ',I2,5X,'YEAR = ',I4)
  210 FORMAT(1H0,1X,'CODE FOR DAY OF WEEK = ',I1)
      RETURN
      END
C
C
      SUBROUTINE SEASON(A1,A2,PARMS,GPARMS,NUM,NREF1)
C
C...SUBROUTINE TO COMPUTE SEASONAL ADJUSTMENT FACTORS FOR MICROENVIRONME
      COMMON /K1/IM,ID,IY
      DIMENSION GPARMS(14,2),PARMS(14,2),CONTRL(14)
      WRITE(6,2000)
 2000 FORMAT(1H0,1X,'SEASONAL CORRECTIONS FOR MICROENVIRONMENT NO. 6:')
      WRITE(6,2001)   A1,A2
 2001 FORMAT(1H0,5X,'COSINE MIN. = ',F5.2,7X,'COSINE MAX. = ',F5.2)
C...FIND CODE FOR JANUARY 1 OF YEAR SELECTED BY USER
      IJAN=IY-1900+0100+010000
C...DETERMINE REFERENCE DATE FOR FIRST DAY OF YEAR
      CALL CALNDR(IJAN,IDAY,NREF2)
C...DETERINE DAY OF YEAR
      JDIFF=NREF1-NREF2
      T=FLOAT(JDIFF)
      WRITE(6,2005)   JDIFF
 2005 FORMAT(1H0,5X,'DATE SELECTED BY USER CORRESPONDS TO THE',
     1I4,' TH DAY OF THE YEAR')
C...DETERMINE SEASONAL CORRECTION OF ARITH. MEAN FOR THAT DATE
      PI=3.14
      AVE=((A2-A1)/2.0)*(1.0+COS(2.0*PI*T/365.0))+A1
      WRITE(6,2010)   AVE
 2010 FORMAT(1H0,5X,'SEASONALLY ADJUSTED ARITHMETIC MEAN FOR MICRO. NO.
     16 = ',F7.4)
C...COMPUTE ARITH. STANDARD DEV. BASED ON EL CAMINO DATA
      STD=AVE*1.107+0.7
C...COMPUTE NORMAL PARAMETERS
      SIG=SQRT(ALOG((AVE*AVE/STD*STD)+1.0))
      U=ALOG(AVE) - 0.5*SIG*SIG
      PARMS(6,1)=SIG
      GPARMS(6,2)=SIG
C...COMPUTE GEOMETRIC PARAMETERS
      SG=EXP(SIG)
      UG=EXP(U)
      GPARMS(6,2)=SG
      UGO=GPARMS(6,1)
      GPARMS(6,1)=UG
C...COMPUTE RELATIVE CONTROL
      CONTL=UGO/UG
      I=6
C...PRINT RESULTS
      WRITE(6,2020) I,UG,SG,CONTL,UG,AVE,STD,U,SIG
 2020 FORMAT(1H0,8X,I2,11X,F7.4,6X,F7.4,11X,F7.4,14X,F7.4,6X,F7.4,
     13X,F7.4,9X,F7.4,3X,F7.4)
      I=1
      RETURN
      END
C
C
      SUBROUTINE SELECT(J,ISEX,A,H,W,HB,JOB,INSTR3)
C
C...SUBROUTINE TO SELECT A RESPONDENT FROM THE U.S. POPULATION
      COMMON /D1/N1,N2,N3,N4,N5,N21,N22,N6,N7
      COMMON /D2/CSEX(25,2),CAGEF(25,2),CAGEM(25,2)
      COMMON /D3/CHTF(25,2),CHTM(25,2),CHBF(25,2),CHBM(25,2)
      COMMON /D4/CEMPF(25,2),CEMPM(25,2)
    1 CONTINUE
C...SELECT SEX: 1 = FEMALE; 2 = MALE
      PX1=CSEX(1,2)
      PX2=CSEX(2,2)-PX1
      CALL ANY2(ISEX,PX1,PX2)
C...DETERMINE AGE BASED ON CONDITIONAL AGE DISTRIBUTION
   50 IF(ISEX.EQ.1)   CALL ANYDIS(A,N2,CAGEF,0.0)
      IF(ISEX.EQ.2)   CALL ANYDIS(A,N3,CAGEM,0.0)
      IF(A.LT.18..OR.A.GT.65.) GO TO 50
C...DETERMINE HEIGHT AND WEIGHT BASED ON HANES II DATA
      GO TO (100,200), ISEX
  100 CALL ANYDIS(H,N4,CHTF,48.0)
C
C...DETERMINE WEIGHT BASED ON AGE AND HEIGHT
      IF(A.GE.18.AND.A.LE.24) W=-56.28+2.965*H
      IF(A.GE.25.AND.A.LE.34) W=-88.62+3.587*H
      IF(A.GE.35.AND.A.LE.44) W=-94.02+3.815*H
      IF(A.GE.45.AND.A.LE.54) W=-77.17+3.587*H
      IF(A.GE.55.AND.A.LE.64) W=-68.24+3.492*H
      IF(A.GE.65.AND.A.LE.74) W=-76.38+3.583*H
      GO TO 300
  200 CALL ANYDIS(H,N5,CHTM,54.0)
C
C...DETERMINE WEIGHT BASED ON AGE AND HEIGHT
      IF(A.GE.18.AND.A.LE.24) W=-172.63+4.842*H
      IF(A.GE.25.AND.A.LE.34) W=-168.67+4.941*H
      IF(A.GE.35.AND.A.LE.44) W=-187.49+5.277*H
      IF(A.GE.45.AND.A.LE.54) W=-131.83+4.454*H
      IF(A.GE.55.AND.A.LE.64) W=-173.99+5.069*H
      IF(A.GE.65.AND.A.LE.74) W=-131.64+4.385*H
C
  300 CONTINUE
C
C...DETERMINE HEMOGLOBIN CONTENT BASED ON HANES II DATA
      IF(ISEX.EQ.1) CALL ANYDIS(HB,N21,CHBF,7.0)
      IF(ISEX.EQ.2) CALL ANYDIS(HB,N22,CHBM,7.0)
C
      JOB=1
C...CASES FOR WHICH PROGRMMING IS NOT YET COMPLETED (JOB= 2,3,4,5,6)
C.....IF AGE IS FROM 6 TO 16, PERSON IS ASSUMED A TO BE A SCHOOL STUDENT
C     IF(A.GE.6.0.AND.A.LE.16.0)   JOB=3
C     IF(A.LT.6.0)   JOB=4
C.....IF THE AGB EXCEEDS 65, THE PERSON IS ASSUMED TO BE RETIRED
C     IF(A.GT.65.0)   JOB=5
C
C...DETERMINE EMPLOYMENT STATUS FOR PERSONS AGED 18-65
C     IF(A.GE.18..AND.A.LE.65..AND.ISEX.EQ.1)  CALL INYDIS(JOB,N6,CEMPF)
C     IF(A.GE.18..AND.A.LE.65..AND.ISEX.EQ.2)  CALL INYDIS(JOB,N7,CEMPM)
      IF (INSTR3.NE.1) GO TO 3
      IF(ISEX.EQ.1)  WRITE(6,2102) J,A,H,W,JOB
      IF(ISEX.EQ.2)  WRITE(6,2103) J,A,H,W,JOB
 2102 FORMAT(/,1X,'PERSON NO.',I6,7X,'SEX: FEMALE',7X,'AGE:',F5.0,7X,
     1'HEIGHT:',F5.0,7X,'WEIGHT:',F5.0,7X,'OCCUPATIONAL CATEGORY:',I3)
 2103 FORMAT(/,1X,'PERSON NO.',I6,7X,'SEX: MALE',7X,'AGE:',F5.0,7X,
     1'HEIGHT:',F5.0,7X,'WEIGHT:',F5.0,7X,'OCCUPATIONAL CATEGORY:',I3)
    3 CONTINUE
      RETURN
      END
```

```
C
C
      SUBROUTINE COMUTR(IACT,RMET,INSTR1,ADD)
C
C...SUBROUTINE TO CONSTRUCT ACTIVITIES OF A COMMUTER (EMPLOYED PERSON)
      COMMON /C1/IA
      COMMON /C3/CWORKA(25.2),CMODE(25.2),CTRIP1(25.2),CTRIP2(25.2)
      COMMON /C4/DMODE(25.2),DTRIP(25.2),SMODE(25.2),STRIP(25.2)
      COMMON /C5/N8,N9,N10,N11,N12,N13,N14,N15,GPROB,SPROB
      DIMENSION IACT(1440),RMET(1440)
C
C  * * *  DETERMINE MORNING COMMUTE ACTIVITIES  * * *
C
C   TA1/MTA1: TIME OF ARRIVAL AT PLACE (FRONT DOOR) OF EMPLOYMENT
C   MTD1: TIME OF DEPARTURE FROM HOME (BEGINNING OF MODE)
C   TRIP/ITRIP: TIME DURATION OF HOME-WORK TRIP (TIME DURING MODE)
C   MTC1: TIME THAT HOME-WORK TRIP MODE ENDS (CONNECTING TRIP BEGINS)
C
C... PICK THE WORK ARRIVAL TIME: TA1
      CALL ANYDIS(TA1,N8,CWORKA,1.0)
      IF(INSTR1.EQ.1)   WRITE(6,2201) TA1
 2201 FORMAT(1H0.5X,'WORK ARRIVAL TIME =',F6.2)
C...CONVERT TO MINUTES
      TA1=TA1*60.0
      MTA1=IFIX(TA1)
      IACT(MTA1)=3
C...DETERMINE THE TRAVEL MODE
      CALL INYDIS(MODE,N9,CMODE)
      IF(INSTR1.EQ.1)   WRITE(6,2205)   MODE
 2205 FORMAT(1H .5X,'HOME-WORK TRAVEL MODE =',I3)
C...DETERMINE HOME-WORK TRIP TIME (DURATION OF MODE)
C.......IF MODE IS BY PRIVATE TRANSPORTATION, FIND TRIP TIME
      IF(MODE.EQ.6.OR.MODE.EQ.9)    CALL ANYDIS(TRIP,N10,CTRIP1,0.0)
C......IF MODE IS BY PUBLIC TRANSPORTATION, FIND TRIP TIME
      IF(MODE.EQ.7.OR.MODE.EQ.10)   CALL ANYDIS(TRIP,N11,CTRIP2,0.0)
      TRIP=TRIP+ADD
      IF(INSTR1.EQ.1)   WRITE(6,2210)   TRIP
 2210 FORMAT(1H .5X,'TRIP TIME DURING HOME-WORK TRAVEL MODE = ',F7.2)
C...CONVERT TRIP TIME TO INTEGER FORM
      TRIP=TRIP+0.5
      ITRIP=IFIX(TRIP)
C...FIND TIME OF END OF HOME-WORK TRAVEL MODE: ARRIVAL TIME MINUS 10 MIN
      MTC1=MTA1-10
C...IF THE TRIP IS BY AUTO, DETERMINE IF PARKING IS IN AN INDOOR GARAGE
      CALL ANY(K.GPROB)
C...IF TRIP IS BY AUTO, STORE PARKING STATUS IN ACTIVITY VECTOR
C......PARKING IS IN AN INDOOR GARAGE
      IF(MODE.EQ.6.AND.K.EQ.1)   IACT(MTC1)=5
C......PARKING IS NOT IN AN INDOOR GARAGE
      IF(MODE.EQ.6.AND.K.EQ.0)   IACT(MTC1)=12
C......TRIP IS NOT BUY AUTO, SO PARKING IS NOT NEEDED
      IF(MODE.NE.6)   IACT(MTC1)=12
C...FIND MORNING DEPARTURE TIME BY SUBTRACTING COMMUTE TRAVAL MODE TIME
C...FROM BEGINNING OF TRIP CONNECT TIME
      MTD1=MTC1-ITRIP
      IF(INSTR1.EQ.1)   WRITE(6,2215)   MTD1
 2215 FORMAT(1H .8X,'PERSON DEPARTED HOME AT',I5,' TH MINUTE')
      IF(INSTR1.EQ.1)   WRITE(6,2216)   MTC1
 2216 FORMAT(1H .8X,'COMMUTE TRIP ENDED AT',I5,' TH MINUTE')
      IF(INSTR1.EQ.1)   WRITE(6,2217)   MTA1
 2217 FORMAT(1H .8X,'ARRIVED AT WORK (FRONT DOOR) AT',I5,' TH MINUTE')
```

```
C...STORE DEPARTURE TIME AND MODE IN ACTIVITY VECTOR
      IACT(MTD1)=MODE
C
C  * * *  DETERMINE EVENING COMMUTE ACTIVITIES  * * *
C
C   MTC2: TIME OF START OF EVENING RETURN CONNECTING TRIP
C   MTD2: TIME OF START OF RETURN COMMUTE (BEGINNING OF MODE)
C   MTA2: EVENING TIME OF ARRIVAL AT HOME (END OF TRAVEL MODE)
C
C...DETERMINE RETURN CONN. TRIP MTC2; IT IS 9 HR LATER BY THE SAME MODE
      MTC2=MTA1+540
C...DETERMINE CONNECTING TRIP END TIME BY ADDING 10 MIN TO MTC2
      MTD2=MTC2+10
C...SET CONNECTING TRIP MODE THE SAME AS EARLIER CONNECTING TRIP
      IACT(MTC2)=IACT(MTC1)
C...RETURN COMMUTE MUST BE BY SAME MODE AS FORWARD COMMUTE
      IACT(MTD2)=IACT(MTD1)
      MTA2=MTD2+ITRIP
      IACT(MTA2)=1
      IF(INSTR1.EQ.1)   WRITE(6,2220)   MTC2
 2220 FORMAT(1H0,8X,'PERSON DEPARTED WORK AT',I5,' TH MINUTE')
      IF(INSTR1.EQ.1)   WRITE(6,2221)   MTD2
 2221 FORMAT(1H ,8X,'BEGAN EVENING COMMUTE AT',I5,' TH MINUTE')
      IF(INSTR1.EQ.1)   WRITE(6,2222)   MTA2
 2222 FORMAT(1H ,8X,'ENDED COMMUTE AT',I5,' TH MINUTE')
C
C  * * *  DETERMINE LUNCH TIME TRAVEL ACTIVITY  * * *
C
C   MTD3: TIME OF LUNCH TRIP DEPARTURE
C   MTA3: TIME OF ARRIVAL AT LUNCH PLACE
C   MTD4: TIME OF DEPARTURE FROM LUNCH PLACE
C   MTA4: TIME OF ARRIVAL AT WORK PLACE
C
C...DETERMINE MODE OF TRANSPORT FOR LUNCH
   10 CALL INYDIS(LMODE,N12,DMODE)
C.....IF COMMUTE DID NOT INVOLE AUTO, LUNCH TRIP BY AUTO IS FORBIDDEN
      IF(MODE.NE.6.AND.LMODE.EQ.6)   GO TO 10
C...LUNCH BEGINS AT A TIME (MTD3) THAT IS UNIFORMLY DISTRIBUTED
C...BETWEEN 11:00 A.M. AND 240 MINUTES AFTER WORK ARRIVAL TIME (MTA1)
      A=660.0
      B=FLOAT(MTA1)+240.0
      RT=RAND(IA)*(B-A)+A
      MTD3=IFIX(RT)
C...ASSUME 10 MINUTE TRAVEL TIME TO LUNCH PLACE
      IACT(MTD3)=LMODE
      MTA3=MTD3+10
      IACT(MTA3)=2
      MTD4=MTA3+40
      IACT(MTD4)=IACT(MTD3)
      IF(INSTR1.EQ.1)   WRITE(6,2250)   IACT(MTD3)
 2250 FORMAT(1H0,5X,'LUNCH TRANSPORTATION MODE = ',I2)
      MTA4=MTD4+10
      IACT(MTA4)=3
      IF(INSTR1.EQ.1)   WRITE(6,2240)   MTD3
 2240 FORMAT(1H ,8X,'TRIP TO LUNCH BEGAN AT',I5,' TH MINUTE')
      IF(INSTR1.EQ.1)   WRITE(6,2241)   MTA3
 2241 FORMAT(1H ,8X,'AND ENDED AT',I5,' TH MINUTE')
      IF(INSTR1.EQ.1)   WRITE(6,2242)   MTD4
 2242 FORMAT(1H ,8X,'LUNCH RETURN TRIP BEGAN AT',I5,' TH MINUTE')
      IF(INSTR1.EQ.1)   WRITE(6,2243)   MTA4
 2243 FORMAT(1H ,8X,'AND ENDED AT',I5,' TH MINUTE')
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```
      GO TO 900
  199 CONTINUE
      JCOUNT=0
      MTEMP=IACT(1)
      I1=1
      DO 200 I=1,1440
      IF(IACT(I).EQ.MTEMP)   JCOUNT=JCOUNT+1
      IF(IACT(I).EQ.MTEMP)   GO TO 200
C...CHANGE IN ACTIVITY DECTECTED: STORE INDEX OF LAST REPEATED ACT. CODE
      I2=I1+JCOUNT-1
C...IF VALUES ARE REPEATED, MODIFY VARIANCE IN ACCORDANCE WITH C.L.T.
C...OTHERWISE, SKIP COMPUTATION OF MODIFIED VARIANCE
      IF(JCOUNT.EQ.1)   CALL SAMLN(X,U,SIG)
      IF(JCOUNT.EQ.1)   GO TO 215
      SIG=PARMS(MTEMP,2)
      IF(SIG.EQ.0.0)   GO TO 225
      U=PARMS(MTEMP,1)
      VAR=SIG*SIG
      AVE=EXP(U+0.5*VAR)
      STD=AVE*SQRT(EXP(VAR)-1.0)
      T=FLOAT(JCOUNT)
      STDMOD=STD/SQRT(T)
      SIGMOD=SQRT(ALOG((STDMOD*STDMOD)/(AVE*AVE)+1.0))
      CALL SAMLN(X,U,SIGMOD)
  215 CONTINUE
C...FILL EXPOSURE ARRAY WITH RESULTING SAMPLED VALUE
      DO 220 J=I1,I2
      CO(J)=X
  220 CONTINUE
      GO TO 240
C...IF ZERO STANDARD DEVIATION, SET CO TO GEO. = ARITH. MEAN
  225 DO 230 K=I1,I2
      CO(K)=GPARMS(MTEMP,1)
  230 CONTINUE
C...STORE I1, RESET JCOUNT, AND STORE LAST ACTIVITY CODE
  240 I1=I2+1
      JCOUNT=1
      MTEMP=IACT(I)
  200 CONTINUE
  900 CONTINUE
      RETURN
      END
C
C
      SUBROUTINE AVEHR1(CO,CO1)
C
C...SUBROUTINE TO COMPUTE HOURLY AVERAGE FROM 1-MINUTE AVERAGE CO DATA
      DIMENSION CO(1440),CO1(24)
C...COMPUTE 1-HR AVERAGE CO CONCENTRATION
      DO 100 I=1,24
      SUM=0.0
      DO 120 J=1,60
      K=J+(I-1)*60
      SUM=SUM+CO(K)
  120 CONTINUE
C...STORE HOURLY AVERAGE VALUE
      CO1(I)=SUM/60.0
  100 CONTINUE
      RETURN
      END
C
```

```
C
C  * * *  PREPARE ACTIVITY VECTOR  * * *
C
C...FILL THE ACTIVITY CODE VECTOR BETWEEN ACTIVITY CODE CHANGES
      CALL FILL(IACT)
C
C  * * * PREPARE METABOLIC RATE VECTOR  * * *
C
      DO 50 I=1,1440
      RMET(I)=1.3
      IF(IACT(I).EQ.1.AND.I.LE.360) RMET(I)=0.7
      IF(IACT(I).EQ.1.AND.I.GT.360) RMET(I)=1.5
      IF(IACT(I).EQ.4) RMET(I)=2.6
      IF(IACT(I).EQ.5.OR.IACT(I).EQ.14) RMET(I)=4.0
      IF(IACT(I).EQ.6) RMET(I)=1.5
      IF(IACT(I).EQ.9) RMET(I)=2.0
      IF(IACT(I).GE.11.AND.IACT(I).LE.13) RMET(I)=2.6
   50 CONTINUE
C
      RETURN
      END
C
C
      SUBROUTINE FILL(IACT)
C
C...SUBROUTINE TO FILL ACTIVITY CODES INTO THE VECTOR IACT (MINUTES)
C...ACTIVITY CODES FOR ONE DAY ARE STORED IN THE VECTOR IACT(1440)
C...EACH ELEMENT OF THE VECTOR REPRESENTS 1 MINUTE OF THE DAY
      DIMENSION IACT(1440)
C...IF A CODE OTHER THAN ZERO IS ENCOUNTERED, REPEAT THIS CODE
C...UNTIL NEXT NONZERO CODE IS ENCOUNTERED
      JTEST=0
      DO 10 I=1,1440
      IF(IACT(I).NE.JTEST.AND.IACT(I).NE.0)   JTEST=IACT(I)
      IACT(I)=JTEST
   10 CONTINUE
      RETURN
      END
C
C
      SUBROUTINE EXPOS(CO,IACT,PARMS,GPARMS,INS5)
C
C...SUBROUTINE TO EXPOSE PERSON TO 1-MINUTE CO CONCENTRATIONS
C...BASED ON ACTIVITIES CONTAINED IN IACT AND LOGNORMAL PARAMETERS
      DIMENSION IACT(1440),CO(1440)
      DIMENSION PARMS(14,2),GPARMS(14,2)
      IF(INS5.EQ.1)   GO TO 199
      DO 100 I=1,1440
      M=IACT(I)
C...SAMPLE FROM DISTRIBUTION CORRESPONDING TO THE MTH MICROENVIRONMENT
      SIG=PARMS(M,2)
      IF(SIG.EQ.0.0)   GO TO 110
      U=PARMS(M,1)
      CALL SAMLN(X,U,SIG)
      CO(I)=X
      GO TO 120
  110 CONTINUE
C...IF ZERO STANDARD DEVIATION, SET CO TO GEO. = ARITH. MEAN
      CO(I)=GPARMS(M,1)
  120 CONTINUE
  100 CONTINUE
```

```
C
      SUBROUTINE AVEHR8(CO1,CO8,K)
C
C...SUBROUTINE TO COMPUTE 8-HR RUNNING AVERAGES FOR K HOURS
      DIMENSION CO1(24),CO8(32),CO1A(24)
C...CLEAR 8-HR AVERAGE CO ARRAY
      DO 20 I=1,31
      CO8(I)=0.0
   20 CONTINUE
C...COMPUTE 8-HR RUNNING AVERAGE
      DO 100 I=1,K
      SUM8=0.0
      L=I+7
      DO 120 J=I,L
      SUM8=SUM8+CO1(J)
  120 CONTINUE
      CO8(L)=SUM8/8.0
  100 CONTINUE
      RETURN
      END
C
C
      SUBROUTINE BLOOD(ICON,COT1,RMET1,N,FCOHB,COHB,A,H,W,
     1HB,ALT,HALD,VCO,BV,DLB,IDT,INSTR4)
C
C...SUBROUTINE TO COMPUTE BLOOD CARBOXYHEMOGLOBIN (COHB) FROM HOURLY CO
      DIMENSION COT1(24),RMET1(24),COHB(24)
C
      YPRE=FCOHB/100.
      BV=-4670+46.6*H*2.54+21.6*W/2.2
      PB=760.*EXP(-.0000386*ALT)
      PCO2=100-137.4*0.0000386*ALT
      DLB=-61.-.075*A+1.131*H+.975*HB
      IF(IDT.EQ.1.OR.INSTR4.EQ.0) GO TO 25
      IF (ICON.EQ.1) WRITE (6,310)
      IF (ICON.EQ.2) WRITE (6,320)
      WRITE(6,330)
      WRITE(6,340)
  310 FORMAT (/,'  COHB ESTIMATED BY LINEAR METHOD',/)
  320 FORMAT (/,'  COHB ESTIMATED BY NONLINEAR METHOD',/)
  330 FORMAT(1H1)
  340 FORMAT(//,'HOUR',8X,'VA',8X,'DL',7X,'R',9X,'C',5X,'COHBE',
     16X,'K ',6X,' M ',5X,'COHB',5X,'T',5X,'ENDCO'/)
C
C  * * *  COMPUTATATION LOOP  * * *
C
   25 DO 50 I=1,N
C
      M=0
      VA=7.5*(1+RMET1(I)-0.8)*1000
      DL=DLB+4.5*(RMET1(I)-0.8)
      R=1/DL+(PB-47)/VA
      C=HALD*(R*VCO+(PB-47)*.000001*COT1(I))/PCO2
      COHBE=C/(1+C)
      VALUK1=PCO2/(HALD*BV*.0139*HB*(1-YPRE)*R)
      F1=EXP(-60*VALUK1)
      VALUEK=PCO2/(HALD*BV*.0139*HB*(1-COHBE)*R)
      F=EXP(-60*VALUEK)
      ENDCO=VCO*HALD*(1-COHBE)*R/PCO2
      IF (ICON.GT.1) GO TO 22
C
```

```
C...LINEAR SOLUTION
C
      COHB(I)=YPRE*F1+C*(1-F1)*(1-YPRE)
      IF(COHB(I).GT.1) COHB(I)=0.0
      YPRE=COHB(I)
      GO TO 49
C
C...NONLINEAR SOLUTION
C
   22 Z1=YPRE
      Z2=COHBE
   39 ZNEW=YPRE*F+C*(1-F)*(1-YPRE)
   40 IF (ZNEW.EQ.COHBE) GO TO 60
      IF (COHBE.EQ.YPRE) GO TO 60
      RATIO=(YPRE-COHBE)/(ZNEW-COHBE)
      IF(RATIO.LT.0) GO TO 70
      IF(RATIO.GT.100000000.) GO TO 60
      T=((ZNEW-YPRE)+(1-COHBE)*ALOG(RATIO))/VALUEK
      IF(T.GE.59.9.AND.T.LE.60.1) GO TO 60
      IF(T.LT.59.9) GO TO 41
      F=EXP(-(60-(T-60)-1)*VALUEK)
      Z2=ZNEW
      M=M+1
      IF (M.EQ.1) GO TO 39
      GO TO 42
   41 IF(T.LT.59.9) Z1=ZNEW
       F=EXP(-(60+(60-T)+1)*VALUEK)
      M=M+1
       IF (M.EQ.1) GO TO 39
   42 ZNEW=(Z1+Z2)*0.5
      IF(M.LE.15) GO TO 40
   60 COHB(I)=ZNEW
      IF(COHB(I).GT.1) COHB(I)=0.0
      YPRE=ZNEW
   49 IF (IDT.EQ.1.OR.INSTR4.EQ.0) GO TO 50
      WRITE(6,333) I,VA,DL,R,C,COHBE,VALUEK,M,COHB(I),T,ENDCO
  333 FORMAT(1X,I2,6X,F8.0,1X,F8.2,1X,F8.5,1X,F8.5,1X,F8.7,1X,F8.7,
     14X,I2,4X,F8.7,F6.2,F9.6)
   50 CONTINUE
C
C...CHANGE TO PERCENT CONCENTRATION
   70 DO 80 I=1,24
      COHB(I)=COHB(I)*100.
   80 CONTINUE
      RETURN
      END
C
C
      SUBROUTINE VMAX24(VAL,VALMAX)
C
C...SUBROUTINE TO FIND THE MAXIMUM OF 24 VALUES IN THE VECTOR VAL
      DIMENSION VAL(24)
      VALMAX=-9999999.0
      DO 10 I=1,24
      TEST=VAL(I)
      IF(TEST.GT.VALMAX)   VALMAX=TEST
   10 CONTINUE
      RETURN
      END
C
C
```

```
      SUBROUTINE VMAX32(VAL,VALMAX)
C
C...SUBROUTINE TO FIND THE MAXIMUM OF 32 VALUES IN THE VECTOR VAL
      DIMENSION VAL(32)
      VALMAX=-9999999.0
      DO 10 I=1,32
      TEST=VAL(I)
      IF(TEST.GT.VALMAX)   VALMAX=TEST
   10 CONTINUE
      RETURN
      END
C
C
      SUBROUTINE SAMLN(X,U,SIG)
C
C...SUBROUTINE TO SAMPLE FROM A LOGNORMAL DISTRIBUTION
C...WITH LOGARITHMS DISTRIBUTED NORMALLY WITH MEAN U AND STD. DEV. SIG
C......OBTAIN A UNIFORMLY DIST. RANDOM VARIABLE BETWEEN 0 AND 1
      COMMON /C1/IA
      Z=RAND(IA)
C......OBTAIN A NORMALLY DISTRIBUTED R. V. WITH MEAN 0 AND STD. DEV. 1
      RN=GCDFI(Z)
C......COMPUTE A NORMALLY DIST. R.V. WITH MEAN U AND STD. DEV. SIG
      RN=RN*SIG+U
C......COMPUTE A LOGNORMALLY DISTRIBUTED R. V.
      RLN=EXP(RN)
      X=RLN
      GO TO 99
   99 CONTINUE
      RETURN
      END
C
C
      SUBROUTINE ANY(K,P)
C
C...SUBROUTINE SELECTS AN INTEGER RANDOM VARIABLE 0,1
C WITH PROBABILITY SPECIFIED IN THE ARGUMENT: P(1) = P; P(0) = 1-P
      COMMON /C1/IA
      Z=RAND(IA)
      K=99
      IF(Z.GE.0.0.AND.Z.LT.P)   K=1
      IF(Z.GE.P.AND.Z.LT.1.0)   K=0
      IF(K.NE.99)   GO TO 10
      WRITE(6,2001)
 2001 FORMAT(1H0,1X,'MISTAKE: ROUTINE "ANY" HAS FAILED')
   10 CONTINUE
      RETURN
      END
C
C
      SUBROUTINE ANY2(K,P1,P2)
C
C...SUBROUTINE SELECTS AN INTEGER RANDOM VARIABLE 1,2
C...ACCORDING TO THE PROBABILITY SPECIFIED IN THE ARGUMENT
      COMMON /C1/IA
      K=99
      Z=RAND(IA)
      SUM=P1+P2
      IF(SUM.NE.1.0)   GO TO 99
      IF(Z.GE.0.0.AND.Z.LT.P1)   K=1
      IF(Z.GE.P1.AND.Z.LT.SUM)   K=2
      IF(K.NE.99)   GO TO 10
   99 WRITE(6,2001)
 2001 FORMAT(1H0,1X,'MISTAKE: ROUTINE "ANY2" HAS WRONG INPUT VALUES')
   10 CONTINUE
      RETURN
      END
C
C
      SUBROUTINE ANY4(K,P1,P2,P3,P4)
C
C...SUBROUTINE SELECTS AN INTEGER RANDOM VARIABLE 1,2,3,4
C...ACCORDING TO THE PROBABILITY SPECIFIED IN THE ARGUMENT
      COMMON /C1/IA
      COMMON /C2/PR(12)
      PR(1)=P1
      PR(2)=P2
      PR(3)=P3
      PR(4)=P4
      K=0
      Z=RAND(IA)
      S2=0.0
      DO 10 I=1,4
C...ADD PROBABILITIES UNTIL THEY EXCEED Z; THEN Z LIES IN
C...THE KTH INTERVAL
      S2=S2+PR(I)
      IF(S2.GE.Z) K=I
C...DEPART LOOP AS SOON AS K IS SET
      IF(K.NE.0)  GO TO 100
   10 CONTINUE
  100 CONTINUE
      RETURN
      END
C
C
      SUBROUTINE ANY8(K,P1,P2,P3,P4,P5,P6,P7,P8)
C
C...SUBROUTINE SELECTS AN INTEGER RANDOM VARIABLE 1,2,3,4,5,6,7,8
C C...ACCORDING TO THE PROBABILITY SPECIFIED IN THE ARGUMENT
      COMMON /C1/IA
      COMMON /C2/PR(12)
      PR(1)=P1
      PR(2)=P2
      PR(3)=P3
      PR(4)=P4
      PR(5)=P5
      PR(6)=P6
      PR(7)=P7
      PR(8)=P8
      K=0
      Z=RAND(IA)
C...ADD UP THE PROBABILITIES UNTIL THEY EXCEED Z;
C...THEN Z LIES IN THE KTH INTERVAL
      S2=0.0
      DO 10 I=1,8
      S2=S2+PR(I)
      IF(S2.GE.Z)  K=I
C...DEPART LOOP AS SOON AS K IS SET
      IF(K.NE.0)  GO TO 100
   10 CONTINUE
  100 CONTINUE
      RETURN
      END
C
C
      SUBROUTINE INYDIS(K,N,CX)
C
C...SUBROUTINE SELECTS AN INTEGER RANDOM VARIABLE
C C...ACCORDING TO THE PROBABILITY SPECIFIED IN THE ARGUMENT
      COMMON /C1/IA
      DIMENSION CX(25,2)
      K=0
      Z=RAND(IA)
C...EXAMINE THE CUMULATIVE PROBABILITIES UNTIL THEY EXCEED Z;
C...THEN Z LIES IN THE KTH INTERVAL
      DO 10 I=1,N
      T2=CX(I,2)
      IF(T2.GE.Z)  K=CX(I,1)
      IF(K.NE.0)  GO TO 100
   10 CONTINUE
  100 CONTINUE
      RETURN
      END
C
C
      SUBROUTINE ANYDIS(X,N,CX,AMIN)
C
C...SUBROUTINE SELECTS A RANDOM VARIABLE X FOR THE CUMULATIVE FRACTILES
C...THAT ARE STORED IN THE VECTOR CX(N,2); N MUST NOT EXCEED 20
C...CX(I,1) GIVES THE VALUE OF X; CX(I,2) GIVES THE CUMULATIVE FRACTILES
      DIMENSION CX(25,2)
      COMMON /C1/IA
C......SELECT RANDOM NUMBER
      Z=RAND(IA)
C......FIND THE INTERVAL CONTAINING Z BY INCREASING CX(I,2) UNTIL IT
C......EXCEEDS Z, GIVING (CX(I-1,2).LE.Z.AND.CX(I,2).GT.Z)
      MEM=0
      DO 10 J=1,N
      IF(CX(J,2).GT.Z)   MEM=J
      IF(CX(J,2).GT.Z)   GO TO 20
   10 CONTINUE
   20 CONTINUE
C......ERROR CHECK
      IF(MEM.EQ.0)  GO TO 100
C...DETERMINE X USING LINEAR MODEL
C...SET A1,B1 TO 0.0 IF FIRST INTERVAL IS CHOSEN
      I=MEM-1
      IF(I.EQ.0)   A1=AMIN
      IF(I.NE.0)   A1=CX(I,1)
      IF(I.EQ.0)   B1=0.0
      IF(I.NE.0)   B1=CX(I,2)
      I=J
      A2=CX(MEM,1)
      B2=CX(MEM,2)
      X=(Z-B1)*(A2-A1)/(B2-B1) + A1
  100 CONTINUE
      RETURN
      END
C
C
      FUNCTION RAND(IA)
C
C...SUBROUTINE TO GENERATE A (FLOATING) RANDOM VAR. FROM A UNIFORM DIST.
```

```
C...APPROACH USE'S MAGE SUGGESTED IMPROVEMENTS
    1 CONTINUE
      IA=IA*65549
      IF(IA) 5,6,6
C...IF VALUE IS NEGATIVE, IT IS INCREMENTED AND MADE POSITIVE
    5 IA=IA+2147483647+1
    6 S=FLOAT(IA)
C...DIVIDE BY THE LARGEST NO. POSSIBLE IN IBM 360: 2**31 - 1
      ID=2147483647
      D=FLOAT(ID)
      P=S/D
C...UNDERFLOW/OVERFLOW PROTECTION
      IF(P.LT.0.0.OR.P.GT.1.0)   GO TO 1
      RAND=P
      RETURN
      END
C
C
      SUBROUTINE STAT(N,VALUE)
C
C...SUBROUTINE TO COMPUTE STATISTICAL MOMENTS
      COMMON /H1/AVE,STD
      DIMENSION VALUE(2000)
      IF (N.EQ.1)   GO TO 50
C...COMPUTE MEAN
      T=FLOAT(N)
      SUM=0.0
      DO 10 I=1,N
      SUM=SUM+VALUE(I)
   10 CONTINUE
      AVE=SUM/T
      WRITE(6,200) N
      WRITE(6,210) AVE
C...COMPUTE OTHER MOMENTS
      SUM2=0.0
      SUM3=0.0
      SUM4=0.0
      DO 20 I=1,N
      D=VALUE(I)-AVE
      Z2=D*D
      Z3=D*Z2
      Z4=D*Z3
      SUM2=SUM2+Z2
      SUM3=SUM3+Z3
      SUM4=SUM4+Z4
   20 CONTINUE
C...COMPUTE VARIANCE,STANDARD DEVIATION,AND COEFFICIENT OF VARIATION
      S2=SUM2/(T-1.0)
      STD=SQRT(S2)
      COF=STD/AVE
      WRITE(6,220) S2,STD
      WRITE(6,225) COF
C...COMPUTE COEFFICIENT OF SKEWNESS
      IF(S2.EQ.0.0)   GO TO 50
      S3=SUM3/T
      SKEW=S3/(S2**1.5)
      WRITE(6,230) S3,SKEW
C...COMPUTE COEFFICIENT OF KURTOSIS
      S4=SUM4/T
      BETA2=S4/(S2*S2)
      WRITE(6,240) S4,BETA2
```

```
C...FIND LOWEST AND HIGHEST VALUES
      VMAX=-99999999999.0
      VMAX2=-99999999999.0
      VMIN=99999999999.0
      DO 30 I=1,N
      IF(VALUE(I).LT.VMIN)   VMIN=VALUE(I)
      IF(VALUE(I).GT.VMAX)   IMAX=I
      IF(VALUE(I).GT.VMAX)   VMAX=VALUE(I)
   30 CONTINUE
C...FIND SECOND HIGHEST MAXIMUM VALUE
      DO 40 I=1,N
      IF(I.EQ.IMAX)   GO TO 40
      IF(VALUE(I).GT.VMAX2)   VMAX2=VALUE(I)
   40 CONTINUE
      WRITE(6,245) VMIN
      WRITE(6,246) VMAX
      WRITE(6,247) VMAX2
      GO TO 60
   50 CONTINUE
      WRITE(6,250)
  250 FORMAT(1H ,5X,'NO ADDITIONAL STATISTICS POSSIBLE')
   60 CONTINUE
  200 FORMAT(1H0,5X,'N =',I8)
  210 FORMAT(1H0,5X,'MEAN =',F18.8)
  220 FORMAT(1H0,5X,'2ND MOMENT (VAR.) =',F22.10,12X,'STANDARD DEV. =',
     1F20.9)
  225 FORMAT(1H0,10X,'COEFFICIENT OF VARIATION =',F15.8)
  230 FORMAT(1H0,5X,'3RD MOMENT =',F20.9,9X,'COEF. OF SKEWNESS =',F15.8)
  240 FORMAT(1H0,5X,'4TH MOMENT =',F20.9,9X,'COEF. OF KURTOSIS =',F15.8)
  245 FORMAT(1H0,5X,'LOWEST VALUE =',F18.8)
  246 FORMAT(1H0,5X,'HIGHEST VALUE =',F18.9)
  247 FORMAT(1H0,10X,'SECOND HIGHEST VALUE =',F18.9)
      RETURN
      END
C
C
      SUBROUTINE HISTOG(IN,N,VALUE,BASE,DELTA,LIMIT,XI,JH,PV,CUM,
     1HI,IH,IOUTPUT)
C
C...SUBROUTINE TO SORT EACH OF N VALUES INTO INTERVALS OF SIZE DELTA
C IF IN=1, THE VALUES ABOVE THE RANGE ARE LISTED
C...XI CONTAINS THE HISTOGRAM ABSCISSA
C...PV CONTAINS THE INDIVIDUAL FREQUENCIES
C...CUM CONTAINS THE CUMULATIVE FREQUENCIES
C...ILOW IS THE NUMBER OF VALUES BELOW THE RANGE
C...IZERO IS THE NUMBER OF ZERO VALUES
C...IEXCES IS THE NUMBER OF VALUES ABOVE THE RANGE
C...HI CONTAINS THE INDIVIDUAL VALUES ABOVE THE RANGE
C...IOUTPUT IS THE DATA OUTPUT CODE, =0 NO OUTPUT, >0 OUTPUT
      DIMENSION VALUE(2000)
      COMMON /H2/MARK1,MARK2,IBLANK,NLINE(50)
      DIMENSION XI(100),JH(100),PV(100),CUM(100)
      DIMENSION HI(25)
C CLEAR ARRAYS
      DO 1 I=1,100
      JH(I)=0
      PV(I)=0.0
      XI(I)=0.0
      CUM(I)=0.0
    1 CONTINUE
C...CLEAR VALUES
```

```
      ILOW=0
      IZERO=0
      IEXCES=0
C...SET TOP OF RANGE
      TOP=FLOAT(LIMIT)*DELTA + BASE
C BEGIN SORTING ROUTINE
      DO 10 I=1,N
C...DETERMINE IF POINT IS A ZERO VALUE
      IF (VALUE(I).EQ.0.0)  IZERO=IZERO+1
C...MODIFY VALUE TO ADJUST FOR MACHINE DECIMAL CONVERSION ERROR
      PVALUE=VALUE(I) + 0.000001
C...DETERMINE IF POINT IS BELOW RANGE
      IF(PVALUE.GE.BASE)   GO TO 15
      ILOW=ILOW+1
      GO TO 10
   15 CONTINUE
C...DETERMINE IF POINT IS ABOVE RANGE
      IF(PVALUE.LT.TOP)   GO TO 20
      IEXCES=IEXCES+1
      IF(IEXCES.GT.1000)  GO TO 28
      IF(IN.EQ.1)   HI(IEXCES)=VALUE(I)
      GO TO 10
   20 CONTINUE
C...POINT IS WITHIN RANGE; CARRY OUT SORTING
      SDELTA=0.0
      DO 25 J=1,100
      SDELTA=DELTA+SDELTA
      TDELTA=SDELTA+BASE
      IF(PVALUE.LT.TDELTA)   GO TO 27
   25 CONTINUE
   27 CONTINUE
C PVALUE IS GE THAN VALUE(I); THEREFORE INTERVAL HAS BEEN FOUND:
      JH(J)=JH(J)+1
      GO TO 10
   28 CONTINUE
C ERROR: NUMBER OF POINTS ABOVE RANGE EXCEEDS ARRAY SIZE
      IF(IEXCES.EQ.1001)   WRITE(6,2099)
 2099 FORMAT(1H1,2X,'TOO MANY POINTS ARE OUTSIDE RANGE: INCREASE DELTA')
   10 CONTINUE
C TOTAL HISTOGRAM POINTS (THOSE ABOVE BASE)
      NUM=0
      DO 30 I=1,LIMIT
      NUM=NUM+JH(I)
   30 CONTINUE
      NUM=NUM+IEXCES
      S=FLOAT(NUM)
C FILL ABSCISSA, INDIVIDUAL, AND CUMULATIVE FREQUENCY VECTORS
      SUM=0.0
      DO 40 I=1,LIMIT
      XI(I)=(FLOAT(I))*DELTA+BASE
      PV(I)=(FLOAT(JH(I))*100.0)/S
      SUM=SUM+PV(I)
      CUM(I)=SUM
   40 CONTINUE
C CLEAR LINE ARRAY
      DO 50 K=1,50
      NLINE(K)=IBLANK
   50 CONTINUE
C PRINT RESULTS
      WRITE(6,2000) DELTA
      WRITE(6,2001) BASE,ILOW,IZERO
      WRITE(6,2002)
      DO 60 I=1,LIMIT
      Z=PV(I)+0.5
      M=IFIX(Z)
      IF(M.EQ.0)   GO TO 80
      IF(M.GT.50)  M=50
C...FILL LINE ARRAY WITH INDIVIDUAL FREQUENCIES
      DO 70 J=1,M
      NLINE(J)=MARK1
   70 CONTINUE
   80 CONTINUE
C...FILL LINE ARRAY WITH CUMULATIVE FREQUENCIES
      Q=(CUM(I)/2.)+0.5
      L=IFIX(Q)
      IF(L.NE.0)   NLINE(L)=MARK2
C...PRINT ONE LINE
      A=XI(I)-DELTA
      B=XI(I)
      IC=JH(I)
      D=PV(I)
      E=CUM(I)
      F=E*(S/(S+1.0))
      IF(DELTA.LT.0.1) WRITE(6,2003) A,B,IC,D,(NLINE(K),K=1,50),E,F
      IF(DELTA.GE.0.1) WRITE(6,2004) A,B,IC,D,(NLINE(K),K=1,50),E,F
      IF (IOUTPUT.EQ.0) GO TO 85
      IF (CUM(I).EQ.0.AND.CUM(I+1).EQ.0) GO TO 85
      IF(I.GT.1.AND.CUM(I).EQ.100.0.AND.CUM(I-1).EQ.100.0)
     1 GO TO 85
      WRITE(11,1500) IOUTPUT,A,B,IC,D,E
 1500 FORMAT(I2,1X,F7.3,1X,F7.3,1X,I5,1X,F7.3,1X,F7.3)
   85 CONTINUE
C...CLEAR LINE ARRAY
      IF(M.EQ.0)   GO TO 95
      DO 90 K=1,M
      NLINE(K)=IBLANK
   90 CONTINUE
   95 CONTINUE
      IF(L.NE.0)   NLINE(L)=IBLANK
C...CHANGE PAGE
      IF(I.NE.51)   GO TO 60
      WRITE(6,2005)
      WRITE(6,1999)
      WRITE(6,2002)
   60 CONTINUE
C...PRINT BOTTOM OF GRAPH
      WRITE(6,2005)
C...PRINT NO. OF VALUES ABOVE RANGE
      PEXCES=(FLOAT(IEXCES)/S)*100.0
      WRITE(6,2006) TOP,IEXCES,PEXCES
      IH=IEXCES
 1999 FORMAT(1H1)
 2000 FORMAT(1H0,22X,       '*  *  *   DISTRIBUTION OF DATA (INTERVAL WI
     1DTH =',F8.4,')   *  *  *')
C...IF IN=1, PRINT VALUES ABOVE THE RANGE
      IF(IN.NE.1)   GO TO 110
      IF(IEXCES.EQ.0)  GO TO 110
      WRITE(6,2007)
      DO 100 I=1,IEXCES
      WRITE(6,2008) I,HI(I)
  100 CONTINUE
  110 CONTINUE
 2001 FORMAT(1H0,2X,'NO. OF VALUES LESS THAN ',F8.4,'=',I6,5X,
     1'NO. OF ZERO VALUES =',I6)
 2002 FORMAT(1H0,5X,'INTERVAL',5X,'NUMBER',3X,'PERCENT',
     12X,'+---------------------HISTOGRAM---------------------+',
     21X,'CUM. FREQ.',2X,'PLOT POS.')
 2003 FORMAT(1H ,1X,F7.4,'-',F7.4,1X,I7,2X,F7.3,
     1'%',2X,'I',50A1,'I',1X,F7.3,'%',4X,F7.3,'%')
 2004 FORMAT(1H ,1X,F7.2,'-',F6.2,1X,I8,2X,F7.3,
     1'%',2X,'I',50A1,'I',1X,F7.3,'%',4X,F7.3,'%')
 2005 FORMAT(1H ,36X,'+-------------------------------------------------
     1-+')
 2006 FORMAT(1H0,2X,'NO. OF VALUES EQUAL TO OR GREATER THAN ',F9.4,
     1' =',I5,2X,'(',F6.3,'%)')
 2007 FORMAT(1H1,///,8X,'LISTING OF VALUES ABOVE RANGE:',//)
 2008 FORMAT(1H0,12X,I4,5X,F14.6)
      RETURN
      END
C
C
      FUNCTION GAUCDF(X)
C
      DOUBLE PRECISION A
      DIMENSION A(5)
      DATA A/.31938153,-.356563782,1.781477937,
     *-1.821255978,1.330274429/
      IF(X.NE.0.0)  GO TO 1
      GAUCDF=0.5
      RETURN
    1 MEMORY=0
      PDFN=0.39894228*EXP(-0.5*X*X)
      IF(X.GT.0.0)   MEMORY=1
      T=1.0/(1.0+0.2316419*ABS(X))
      SUM=0.0
      V=1.0
      DO 10 I=1,5
      V=T*V
      SUM=SUM+A(I)*V
   10 CONTINUE
      GAUCDF=SUM*PDFN
      IF(MEMORY.EQ.1)   GAUCDF=1.0-GAUCDF
      RETURN
      END
C
C
      FUNCTION GCDFI(Q)
C
      DIMENSION A(3),B(3)
C INVERSE GAUSSIAN CUMULATIVE DISTRIBUTION FUNCTION
      DATA A/2.515517,0.802853,0.010328/
      DATA B/1.432788,0.189269,0.001308/
      P=Q
      IF(P.GT..5) P=1.-P
      ETA=SQRT(ALOG(1./(P*P)))
      XNUM=0.
      DENOM=1.
      ETAP=1.0
      DO 10 I=1,3
      XNUM=XNUM+A(I)*ETAP
      ETAP=ETAP*ETA
   10 DENOM=DENOM+B(I)*ETAP
      GCDFI=XNUM/DENOM-ETA
      IF(P.NE.Q) GCDFI=-GCDFI
      RETURN
      END
/*
```